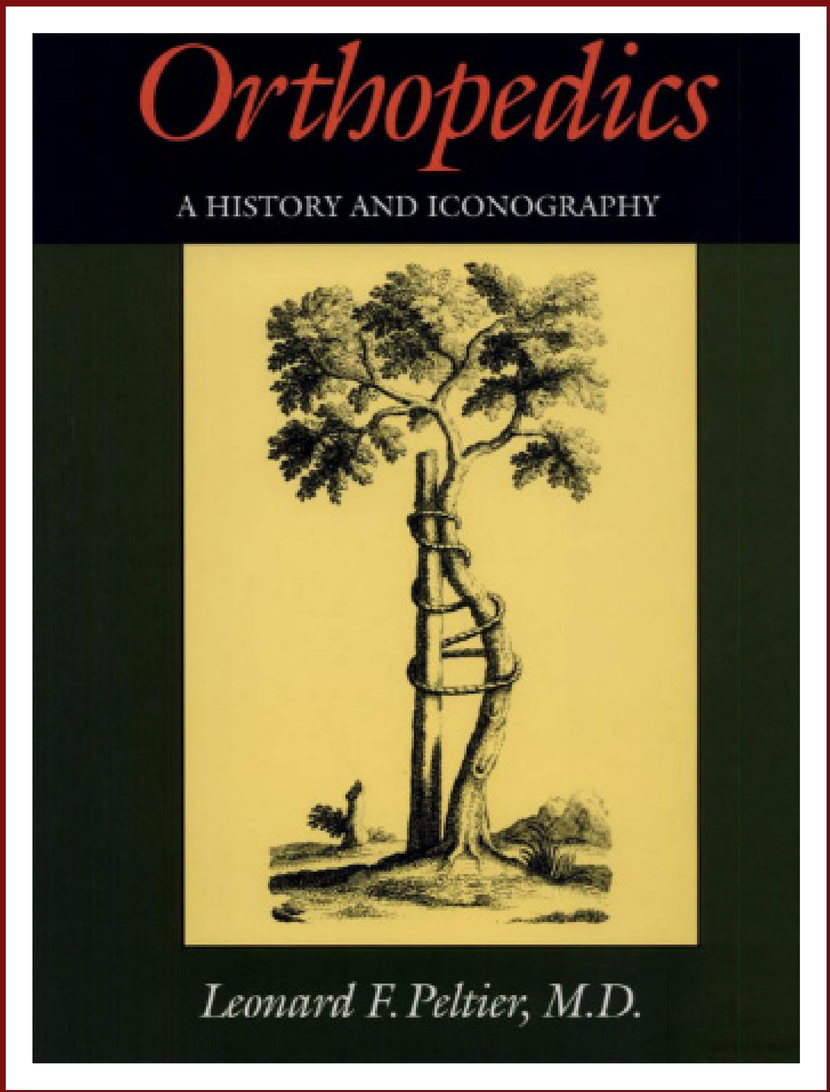
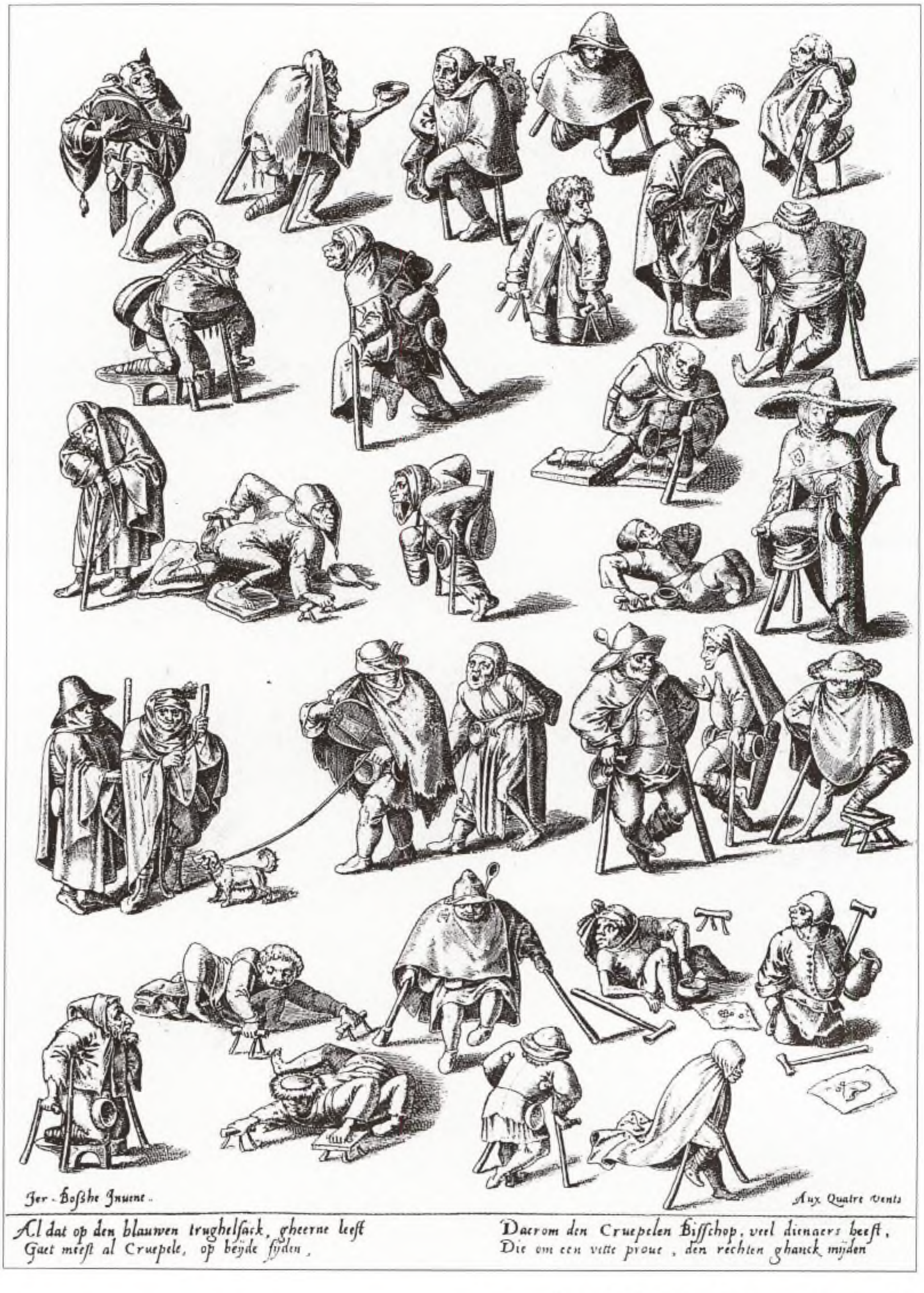
Orthopedics: A History & Iconography



Leonard P. Peltier

Orthopedics

A HISTORY AND ICONOGRAPHY



A Procession of Cripples by Hieronymous Bosch.
From Eugen Hollander,
Die Medizin in der klassischen Malerei
(Stuttgart: Ferdinand Enke, 1903), figure 66.

Orthopedics

A HISTORY AND ICONOGRAPHY

Leonard F. Peltier, M.D.

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Abbreviations

Acta orthop scand *Acta orthopaedica scandinavica*
Acta paed *Acta paediatrica*
Acta rad *Acta radiologica*
Acta scholae med univ imp Kioto *Acta scholae medicinalis universitalis imperialis Kioto*
AMA Arch Surg *The American Medical Association's Archives of Surgery*
Am J Dis Child *American Journal of Disabled Children*
Am J Med Sci *The American Journal of Medical Science*
Am J Orthop *The American Journal of Orthopedics*
Am J Orthop Surg *The American Journal of Orthopedic Surgery*
Am J Roentgenology Rad Ther *American Journal of Roentgenology and Radiation Therapy*
Am J Surg *The American Journal of Surgery*
Am Med Rec *The American Medical Recorder*
Ann Med Hist *Annals of Medical History*
Ann Roy Coll Surg Eng *Annals of the Royal College of Surgeons of England*
Ann Surg *Annals of Surgery*
Arch gén méd *Archives générales de médecine*
Arch klin chir *Archiv für klinische Chirurgie*
Arch Neurol Psychiat *Archives of Neurology and Psychiatry*
Arch ortop *Archiva di ortopedica*
Arch Path *Archives of Pathology*
Arch phys norm path *Archives de la physiologie normale et pathologique*
Arch Surg *Archives of Surgery*
Archs prov chir *Archives provinciales de chirurgie*
Arthroscopy *Arthroscopy: The Journal of Arthroscopic and Related Surgery*
Australian New Zealand J Surg *Australian and New Zealand Journal of Surgery*
Berl klin Wschr *Berlin klinische Wochenschrift*
Berl med Wschr *Berlin medizinische Wochenschrift*
Biochem J *Biochemistry Journal*
Boston Med Surg J *Boston Medical and Surgical Journal*

Brit J Exp Path *British Journal of Experimental Pathology*
Brit J Rheum *British Journal of Rheumatism*
Brit J Surg *British Journal of Surgery*
Brit J Tuberculosis *British Journal of Tuberculosis*
Brit Med J *British Medical Journal*
Bruns Beitr klin Chir *Bruns' Beiträge zur klinischen Chirurgie*
Bull Hosp Joint Dis *Bulletin of the Hospital for Joint Diseases*
Bull Johns Hopkins Hosp *Bulletin, Johns Hopkins Hospital*
Bull mém soc chir Paris *Bulletin et mémoires de la société de chirurgiens de Paris*
Bull sci med Bologna *Bulletino della scienze i mediche di Bologna*
Bull soc chir (Paris) *Bulletin de la société de chirurgie (Paris)*
Bull soc France hist méd *Bulletin de la société de France d'histoire de la médicine*
Cahiers lyon hist méd *Cahiers lyonnais d'histoire de la médecine*
Cancer Res *Cancer Research*
Can J Surg *Canadian Journal of Surgery*
Centralbl Grenz Med Chir *Centralblatt für die Grenzgebiete der Medizin und Chirurgie*
Chicago Med Rec *Chicago Medical Recorder*
Chir org mov *Chirurgia degli organi di movimento*
Ciba Zeit *Ciba Zeitschrift*
Clin Orthop *Clinical Orthopaedics and Related Research*
Clio Med *Clio Medica*
C rend soc biol *Comptes rendus de la société biologique*
Develop Med Child Neur *Developmental Medicine and Child Neurology*
Dtsch klin Wschr *Deutsche klinische Wochenschrift*
Dtsch med Wschr *Deutsche medizinische Wochenschrift*
Dtsch Zeit Chir *Deutsche Zeitschrift für Chirurgie*
Dtsch Zeit Nervenheilk *Deutsche Zeitschrift für Nervenheilkunde*
Edinb Med Surg J *Edinburgh Medical and Surgical Journal*
European J Ped *European Journal of Pediatrics*
Fortschr Med *Fortschritte der Medizin*
Gaz méd Paris *Gazette médicale de Paris*
Gior anat fisiol patol animali *Giornale di anatomia, fisiologia i patologia degli animali*
Illinois Med J *Illinois Medical Journal*
Int Abst Surg *International Abstracts of Surgery*
Int J Rad Onc Biol Phys *International Journal of Radiology: Oncology-Biology-Physics*
Iowa Orthop J *Iowa Orthopaedic Journal*
JAMA *Journal of the American Medical Association*
J Arthro Related Surg *Journal of Arthroscopy and Related Surgery*
J Bio Chem *Journal of Biological Chemistry*

J Bone Joint Surg *Journal of Bone and Joint Surgery (Boston or London)*
J Exp Med *Journal of Experimental Medicine*
J Fac Rad *Journal of the Faculty of Radiologists*
J Hist Med *Journal of the History of Medicine*
J Hist Med Allied Sci *Journal of the History of Medicine and Allied Sciences*
J Med Educ *Journal of Medical Education*
J Neurosurg *Journal of Neurosurgery*
J Orthop Res *Journal of Orhtopaedic Research*
J Ped *Journal of Pediatrics*
J Ped Orthop *Journal of Pediatric Orthopedics*
J Roy Coll Surg Edinb *Journal of the Royal College of Surgeons of Edinburgh*
J Surg Oncol *Journal of Surgery and Oncology*
Königsberg Med J *Königsberg Medical Journal*
Lancet *The Lancet*
Lyon méd *Lyon médicale*
Mag ges Heilk *Magazin der gesampte Heilkunde*
Mayo Clin Proc *Mayo Clinic Proceedings*
Med-Chir Trans *Medico-Chirurgical Transactions*
Med Classics *Medical Classics*
Med Exam *The Medical Examiner*
Med Hist *Medical History*
Méd moderne *La Médecine moderne*
Med News *Medical News*
Med Record *Medical Record*
Med Surg J *Medical and Surgical Journal*
Med Surg Trans *Medical and Surgical Transactions*
Med Times *Medical Times*
Med Times Gaz *Medical Times and Gazette*
Med Trib *The Medical Tribune*
Münch med Wschr *Münchener medizinische Wochenschrift*
N Am Med Surg J *North American Medical and Surgical Journal*
Nebraska State Med J *Nebraska State Medical Journal*
N Eng Med J *The New England Journal of Medicine*
Nouv Presse méd *Nouvelle Presse médicale*
NY Med J *The New York Medical Journal*
NY Quart J Med Surg *The New York Quarterly Journal of Medicine and Surgery*
NY State J Med *New York State Journal of Medicine*
Orthop Clin N Am *Orthopedic Clinics of North America*
Ortop traumatol protez *Ortopediia traumatolgiia i proteziovanie*
Plas Recon Surg *Plastic and Reconstructive Surgery*
Proc NY Path Soc *Proceedings of the New York Pathology Society*
Proc Roy Soc Med *Proceedings of the Royal Society of Medicine*

Progrès méd *Le Progrès médical*
Rev chir *Revue chirurgicale*
Rev chir orthop *Revue de chirurgie orthopédique et réparatrice de l'appareil moteur*
Rev méd *Revue de médicine*
Rev neur Paris *Revue neurologique de Paris*
Richmond Louisville Med J *Richmond and Louisville Medical Journal*
St. George's Hosp Rep *St. George's Hospital Reports*
St. Thomas's Hosp Gaz *St. Thomas's Hospital Gazette*
Samml klin Vort Chir *Sammlung klinische Vortrage: Chirurgie*
Schweiz med Wschr *Schweizenischen medizinsche Wochenschrift*
Sci Am *Scientific American*
Sci med ital *Scientia medica italica*
SGO *Surgery, Gynecology, and Obstetrics*
South Med J *Southern Medical Journal*
Sudhoff's Archiv *Sudhoff's Archiv fuer Geschichte der Medizin und der Naturwissenschaften*
Surg *Surgery*
Surg Clin North Am *The Surgical Clinics of North America*
Surg Forum *Surgical Forum*
Trans Am Med Assoc *Transactions of the American Medical Association*
Trans Am Orthop Assoc *Transactions of the American Orthopedic Association*
Trans Coll Phys Phila *Transactions of the College of Physicians of Philadelphia*
Trans NY Acad Med *Transactions of the New York Academy of Medicine*
Trans NY State Med Soc *Transactions of the New York State Medical Society*
Trans Obstet Soc London *Transactions of the Obstetrical Society of London*
Transplant Proc *Transplant Proceedings*
Verh dtsch Ges Chir *Verhandlungen der deutsche Gesselschaft für Chirurgie*
Verh nat-med Vereins Heidelb *Verhandlungen der naturhistorischen-medizinischen Verein Heidelberg*
Wien med Wschr *Wiener medizinische Wochenschrift*
Wien med Wschr Jahrg *Wiener medizinische Wochenschrift Jahrgang*
Zeit artzl Fortb *Zeitschrift für artzliche Fortbildung*
Zeit Orthop *Zeitschrift für Orthopädie und ihre Grenzgebiete*
Zeit orthop Chir *Zeitschrift für orthopädische Chirurgie, einschliesslich der Heilgymnastik und Massage*
Zentralbl Chir *Zentralblatt für Chirurgie*

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Introduction

Where should a history of orthopedics begin? Deformities of the back and extremities have been observed and treated since time immemorial. Most patients were neglected; a few were treated by bonesetters and other practitioners of folk medicine; occasional patients were seen by physicians. While ancient physicians have left us accurate clinical descriptions of some of their patients, for the most part these anecdotal accounts are marred by the lack of an exact diagnosis. Acknowledging the great debt that we owe to the physicians of the past, I have decided, nevertheless, to begin my history near the middle of the eighteenth century, a seminal period when important medical and social changes were being initiated. It was at this time that significant specialization in different areas of medicine and surgery began. The causes of this were socio-economic. As a result of the industrial revolution, the increasing population was becoming more concentrated in an urban, metropolitan environment. The city hospitals grew in size and became institutions with large numbers of patients. The increase in the number of patients promoted the placement of patients with similar problems together in separate wards. In addition, the growth of the patient population provided a continual flow, at times a torrent, of bodies for autopsy and dissection. An enormous amount of medical knowledge based on these post mortems was accumulated quickly. Simultaneously, there was an increased public awareness of health problems. Among these was the problem of the people with various orthopedic impairments who were known as cripples.*

Specialists are defined by what they do, that is, the types of patients and diseases that they treat. For this reason, this history of orthopedics will be oriented toward the patient and disease rather than toward the physician. It is not meant to be a catalogue of the world's greatest orthopedic practitioners, but rather

*A *cripple* is an individual that is lame or otherwise disabled as a result of injury, disease, or a condition existing since birth. It is an old term of northern European origin and has been used in this sense for over a thousand years; it is a term that is well established in the medical, social, and legal terminology. In the last twenty years, however, *cripple* has assumed a pejorative connotation and for this reason is disappearing from common usage.

an account of how a segment of the medical profession, because of its interaction with patients crippled by disease, defined itself and its specialty. The specialty of orthopedics did not develop in isolation, but grew with the help of many other groups of physicians who were also struggling to establish their own identity. It grew against the background of the scientific and technical advances of the eighteenth, nineteenth, and twentieth centuries. Because the subject is too large to be compressed into one volume in such a way as to do justice to every condition and every individual worthy of note, there must be many errors of omission in this work. For such omissions, I hold myself solely responsible.

Of all of the names proposed for this specialty, and there were many, *orthopedics*, because of its specific relationship to children, may not be the most appropriate. The title of Bouvier's book, *Chronic Diseases of the Locomotor System*, gives a better statement of the dimensions of the specialty. †

† H. Bouvier, *Leçons cliniques sur les maladies chroniques de l'appareil locomoteur* (Paris: J. B. Baillière et Fils, 1858).

CHAPTER ONE

Crippledom or The Condition of Being a Cripple

But I, that am not shaped for sportive tricks,
Nor made to court an amorous looking-glass;
I, that am rudely stamped, and want love's majesty
To strut before a wanton ambling nymph;
I, that am curtailed of this fair proportion,
Cheated of feature by dissembling Nature,
Deformed, unfinished, sent before my time
Into this breathing world, scarce half made up,
And that so lamely and unfashionable
That dogs bark at me as I halt by them.

—*Richard the Third, Act 1, Scene 1*

THIS QUOTATION from *The Tragedy of Richard the Third* by Shakespeare eloquently expresses the personal tragedy of the cripple who is separated from the mainstream of society by the barrier of his deformity and must make his way in the world, often with extraordinary difficulty. Richard had a congenital spastic hemiplegia with a severe kyphoscoliosis.[1] W. J. Little mentions that Sir Thomas More had said, "The Duchess of Gloster had much ado in her travail, he [Richard III] being born the feet forward."[2] No matter how the crippling occurs, by a congenital deformity, as the result of infection, or because of an injury, the result is the same: feelings of isolation and frustration caused by the disability. However, individuals so afflicted can lead successful and fruitful lives, which demonstrates the triumph of the human spirit over adversity.

Cripples have occurred in all societies at all levels, from gods to peasants, and the attitude of society toward them has always been ambivalent. One of the oldest representations of an individual crippled by clubfeet is that of Hephaestus, the god of fire and smiths, known to the Romans as Vulcan (figure 1.1). Hephaestus was born after a premature and difficult labor to Hera, Zeus's wife, and was described as being "short and lame, and he fell down frequently."[3] His wife was the beautiful Aphrodite, whose affair with Ares, the god of war, was duly noted in Homer's *Odyssey*. Having trapped the lovers in a net of chains of his own manufacture, Hephaestus cries

O Father Zeus, O gods in bliss forever, here is indecorous entertainment for you, Aphrodite, Zeus's daughter, caught in the act, cheating me, her cripple with Ares — devastating Ares. Cleanlimbed beauty is her joy, not these bandylegs I came into the world with: no one to blame but the two gods who bred me! [4]

Figure 1.1 A mounted figure of the god Hephaestus, with his bilateral clubfeet, on a small ampora from the sixth century B.C. From C. S. Bartsocas, "Hephaestus and Clubfoot," *J Hist Med Allied Sci* 27(1972): facing p. 451.

There is a great deal of information regarding congenital malformations of men and animals in the ancient literature because the appearance of such "monsters" had great significance as auguries and omens, and were considered important in divining the future.[5] The belief that such births were the portents of disaster was handed down to Western society by the Romans, continued and flourished throughout the Middle Ages, and still persists today in some areas of the world. The cripple, in addition to bearing the burden of his deformity, often had to shoulder the shame and disgrace related to the cause of his deformity, which was attributed to a variety of causes, including the coupling of gods, animals, and devils with women; spells; curses; and the evil eye. Deformity was often a disqualification for the role of priest or priestess. Among the laws concerning the standards for the priesthood of the ancient Jews we find this statement:

For whatsoever man he be that hath a blemish, he shall not approach [the altar]*: a blind man, or a lame, or he that hath a flat nose, or any thing superfluous,*
Or a man that is brokenfooted or brokenhanded,
Or crookbacked, or a dwarf, or that hath a blemish in his eye, or be scurvy, or scabbed, or hath his stones broken.[6]

One of the most persistent and widespread theories of the cause of such deformities was that of maternal impression: the idea that the unborn child could be affected for better or worse by influences perceived by the mother during pregnancy. This same theory was also believed to apply to animals and can be seen in the bargain between Jacob and Laban in which Jacob influenced the number of calves and lambs born "speckled and ringstraked" by exposing the pregnant heifers and ewes to branches that had had the bark removed in such a way as to present a variegated appearance.[7]

While the causes of congenital defects were not understood, the elimination of infants who were malformed was practiced in one way or another for centuries.[8] The laws of Sparta propounded by Lycurgus were quite clear on this subject:

Nor was it in the power of the father to dispose of the child as he thought fit; he was obliged to carry it before certain triers at a place called Lesche; these were some of the elders of the tribe to which the child belonged; their business it was carefully to view the infant, and, if they found it stout and well made, they gave orders for its rearing and allotted it one of the nine thousand shares of land above mentioned for its maintainance, but if they found it puny and ill-shaped, ordered it to be taken to what was called the Apothetae, a sort of chasm under Taygetus; as thinking it neither for the good of the child itself, nor for the public interest, that it should be brought up, if it did not, from the very outset, appear to be healthy and vigorous.[9]

Plato supported this practice, for he says in one of his dialogues that

the proper officers will take the off-spring of the good parents to the pen or fold, and there they will deposit them with certain nurses who dwell in a separate quarter; but the off-spring of the inferior, or of the better when they chance to be deformed, will be put away in some mysterious, unknown place, as they should be.[10]

One cause of deformities that has received little attention is the heinous crime committed by those who made a business of mutilating foundlings and abandoned children for gain. The Roman philosopher Seneca has given this account in one of his *Controversies.* The question was whether those who had mutilated exposed children had done a wrong toward the state.

Look on the blind wandering about the streets leaning on their sticks, and on those with crushed feet, and still again look on those with broken limbs. This one is without arms, that one has had his shoulders pulled down out of shape in order that his grotesqueries may excite laughter. Let us view the entire miserable family shivering, trembling, blind, mutilated, perishing from hunger — in fact, already half dead. Let us go to the origin of all these ills — a laboratory for the manufacture of human wrecks — a cavern filled with the limbs torn from living children — each has a different occupation.

What wrong has been done the Republic? On the contrary, have not these children been done a service inasmuch as their parents had cast them out?

Many individuals rid themselves of misformed children defective in some part of their body or because the children are born under evil auspices. Someone else picks them up out of commiseration and, in order to defray the expense of bringing the child up, cuts off one of its limbs. Today, when they are demanding charity, that life that they owe to the pity of one, they are sustaining at the expense and through the pity of all.

The conclusion was that since the exposed children were slaves, being the property of those who reared them, they had no cause for complaint against the State.[11]

Fielding Garrison, in his history of pediatrics, speaks of *los comprachicos*, a strange affiliation of seventeenth-century criminals who, as in the later Roman Empire, purposely lamed and maimed unfortunate children by a reversed orthopedic procedure called *chirurgie au rebours.*[12] He mentions that in the northwestern provinces of Spain, mothers would frighten their children into obedience by saying, "Aguardate, nino, que voy a llamar a los comprachicos" (Take care child, or I am going to call the comprachicos). It is said that St. Vincent de Paul (1576–1660), the founder of the Congregation of Mission Priests, actually rescued such a child as

Figure 1.2 Lotus feet, the end result of foot-binding. From L. J. Miltner, "Bound Feet in China," *J Bone Joint Surg* 19(1937): 317.

Figure 1.3 An X-ray of a lotus foot. From L. J. Miltner, "Bound Feet in China," 316.

he was being maimed. His interest in foundlings and abandoned children led to the foundation of the Hospice des enfans trouvés in 1640. In the opening chapter of his novel, *L'Homme qui rit* (*The Man Who Laughs*), which deals with the surgical mutilation of a child's face for political motives, Victor Hugo gives the best account of the comprachicos.[13] Similar atrocities were carried out in China.

> *Evil men are constantly stealing children. They put out their eyes or cut off their feet! A thousand tricks they have to injure them so that by exciting compassion they may be the more successful in begging alms.*[14]

Social pressure and custom can lead to crippling, as in the case of foot-binding among the upper-class Chinese women. This custom arose in the tenth century and persisted into the early years of the twentieth century.[15] The process was begun when the child was about six years old and continued throughout her life. The result was an approximation of the metatarsal heads to the posterior portion of the *os calcis*, a change in the long axis of the *os calcis* from a horizontal plane to a more vertical one, that is, a calcaneus deformity, a wedge-shaped deformity of the tarsal bones, and flexion deformities of the outer four toes[16] (figures 1.2 – 1.3). This was accompanied by marked atrophy of the muscles of the leg. It is hard to determine whether such lotus feet, or *golden lilies* as they were called, were the cause of or the result of a male foot fetish, but there is no doubt they were of great erotic significance.

Self-mutilation, such as shooting off the thumb or big toe to avoid military service, may be done as an individual act or by a group. An example of a group action carried out as a form of civil disobedience was reported by Andreas Grisolia. In April 1969 six inmates of the Kansas State Prison in Lansing, Kansas, presented self-inflicted lacerations of the Achilles tendon. During the next eight months, sixty-four other prisoners were seen with similar injuries. Both tendons were divided in fourteen of the prisoners. A variety of instruments were employed to divide the tendons, including glass, pieces of tin, and pocket knives. Only one serious infection occurred and the end result following surgical suture of the tendons was excellent.[17]

The mummies and the walls of the tombs and temples of Egypt have provided many examples of the types of cripples that occurred in Egyptian society (figures 1.4 – 1.6). The statuette of Chnoum-Hotep, the Chief of Perfumes or Head of the Wardrobe, came from his tomb, which was one of the richest at Saqqarah (figure 1.7). It indicates that even though he was an achondroplastic dwarf, he rose to a high position of responsibility in the court of a pharaoh of the Fifth Dynasty (ca. 2700 B.C.).[18] The Romans employed dwarfs, both male and female, for their amusement, and they were very popular, although Augustus is said not to have cared for them.[19] While dwarfs were more common in

Figure 1.4 A foot of the mummy of Pharaoh Siphtah, Nineteenth Dynasty, showing an equinus deformity, probably the result of poliomyelitis. From G. E. Smith, *The Royal Mummies* (Catalogue des Musées du Caire, 1912), pl. 62.

Figure 1.5 A stele of the Eighteenth Dynasty, now in the Glypothek in Copenhagen, showing an individual with a short, atrophic leg and an equinus deformity due to poliomeyelitis. From *Ciba Zeit* 33:1124.

history, occasional note is made of giants, the best known being Goliath of Gath.[20]

The Old Testament also mentions that King David found a son of Jonathan who was a cripple and provided for him in his palace in Jerusalem.

And Jonathan, Saul's son, had a son that was lame of his feet. He was five years old when the tidings came of Saul and Jonathan out of Jezreel, and his nurse took him up, and fled: and it came to pass, as she made haste to flee, that he fell, and became lame. And his name was Mephibosheth.[21]

While the graphic evidence for the presence of cripples among the Greeks is less extensive, Hippocrates was very familiar with a

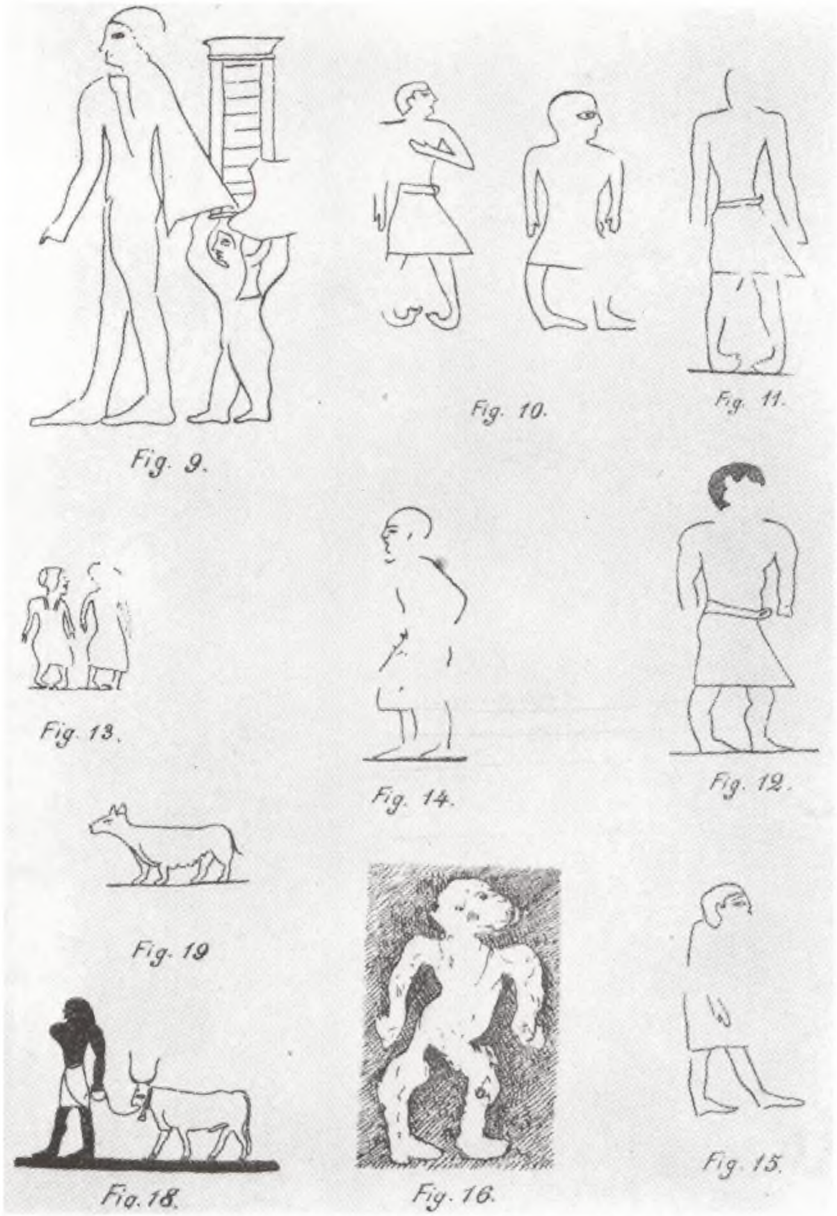

Figure 1.6 A wide variety of deformities, including dwarf animals. Ruffer, *Paleopathology of Egypt*, ed. R. L. Moodie (Chicago: University of Chicago Press, 1921), pl. 9.

wide variety of crippling conditions. There is an interesting vase painting of a physician's clinic of about 400 B.C. showing the physician bleeding a patient while in his waiting room are an amputee leaning on a staff and an achondroplastic dwarf (figure 1.8). The most authentic bust of Aesop (620–560 B.C.), that in the Villa d'Albani in Rome, shows him to have been a hunchback (figure 1.9).

During the period from A.D. 850 to A.D. 1350, there were numerous epidemics of ergotism in western Europe that claimed thousands of lives and left survivors severely handicapped.[22] This was the result of the growth of the fungus, *Claviceps purpurea*, on grain, particularly rye. Weather conditions, such as rainy springs followed by warm summers, favored the growth of the

Figure 1.7 Statuette of the dwarf Chnoum-Hotep, Chief of Perfumes or Head of the Wardrobe. His tomb was one of the richest at Saqqarah. From M. Ruffer, *Studies on the Paleopathology of Egypt*, pl. 7.

Figure 1.8 Figures from a Greek vase of ca. 400 B.C. illustrating a medical clinic. The physician is bleeding a patient while awaiting their turn are an amputee, an achondroplastic dwarf, a man with a dressing on his shoulder, and two other patients. From Charles Singer, *A History of Anatomy and Physiology from the Greeks to Harvey* (New York: Dover Publications Inc., 1957), facing p. 16.

Figure 1.9 A marble bust of Aesop (620–560 B.C.) in the Villa d'Albani in Rome, which suggests that the poet was a victim of tuberculosis of the thoracic spine. From J. M. Charcot and Paul Richer, *Les difformes et les malades dans l'art* (Paris: Lecrosnier et Babe, 1889), 18.

Figure 1.10 A painting by Pieter Brueghel (1525–1569) in the Louvre showing a group of youths with bilateral, symmetrical, below knee amputations, the result of ergotism. From Hans Wurtz, *Zerbrecht die Krucken* (Leipzig: Leopold Voss, 1932), frontispiece.

fungus. The poorer classes, who depended primarily on bread made from the poorest quality of flour for sustenance, were the most frequent victims. The condition was characterized by the loss of circulation to the extremities, which became black, ischemic, and

Figure 1.11 Saint Anthony. Accompanying the saint is a victim of the *Ignis sacer*, or *St. Anthony's fire*, that is, ergotism, with a below knee amputation and residual burning in the upper extremity. Also present is a pig, because St. Anthony was also the patron saint of farm animals.

Figure 1.12. A portion of a mosaic from the Gallo-Roman era in the Cathedral of Lescar, France, showing a below knee amputee with a simple prosthesis. From Vittorio Putti, *Historic Artificial Limbs* (New York: Paul B. Hoeber, 1930), fig. 6.

sloughed off (figure 1.10). Its course was accompanied by a severe burning pain in the extremities; thus the disease was referred to as *Ignis sacer* (the holy fire) or *Ignis plaga* (the fire plague). A case of ergotism due to an overdose of ergotamine tartrate used to treat a severe headache provides a good example of the clinical picture of acute ergotism. The physicians concluded that

> *the clinical evidence suggested that the major lesion was an intense spasm of the arterial tree, including the major arteries of the size of the brachial and superficial femoral vessels. The superficial veins of the skin and the long saphenous trunk were involved in the spasm. The presence of hypercoagulability of the blood was strongly suggested.*[23]

Saint Anthony became identified with the *Ignis sacer*, and it is often referred to as *St. Anthony's fire* (figure 1.11). Saint Anthony (A.D. 251–356) was born and lived out his long life in Egypt and the Middle East.[24] Crusaders brought his relics back to France, where he became the patron saint of fire, inflammations, eczema, and epilepsy, as well as cattle, hogs, other farm animals, farmers, and butchers.[25] It is interesting that the prosthetic devices for below-the-knee amputations that took place as a result of ergotism had been employed for centuries before the Middle Ages (figure 1.12). They were very simple and could be manufactured by any village carpenter. Contrast these with the more elaborate and much more expensive prosthetic devices for both the upper

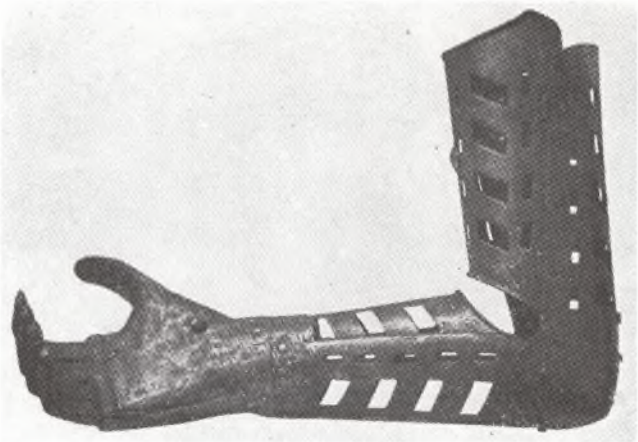

Figure 1.13 A metal upper extremity prosthesis from the sixteenth century with a moveable elbow and fingers.

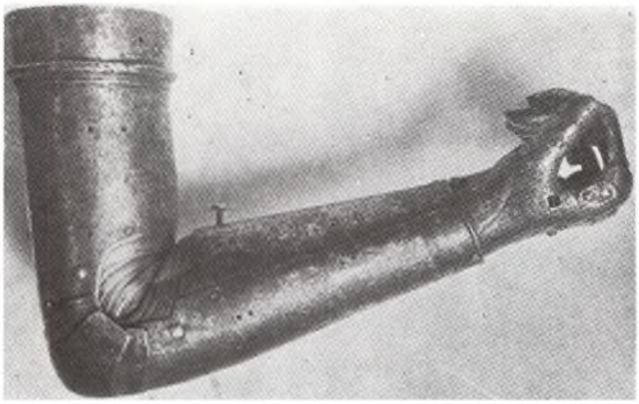

Figure 1.14 An articulated upper-extremity prosthesis from the fifteenth or sixteenth century showing the similarity to the highest-quality armor.

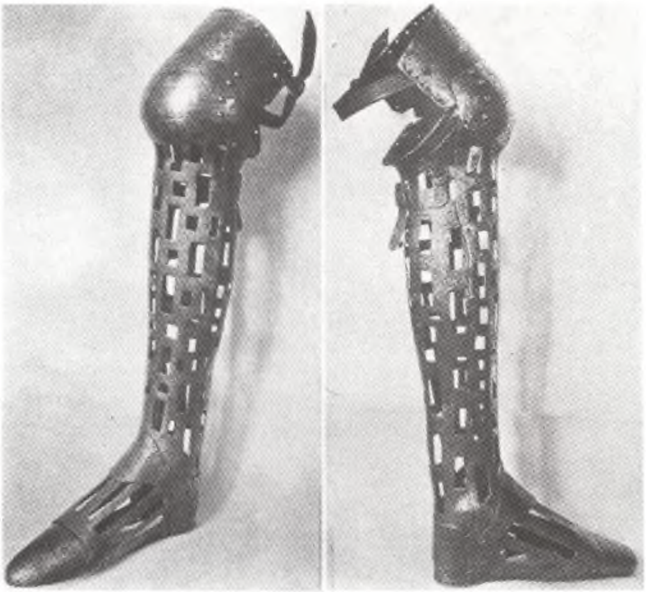

Figure 1.15 An above knee prosthesis from the sixteenth century. The knee is fixed at the proper angle for equitation. The metal is fenestrated to limit weight.

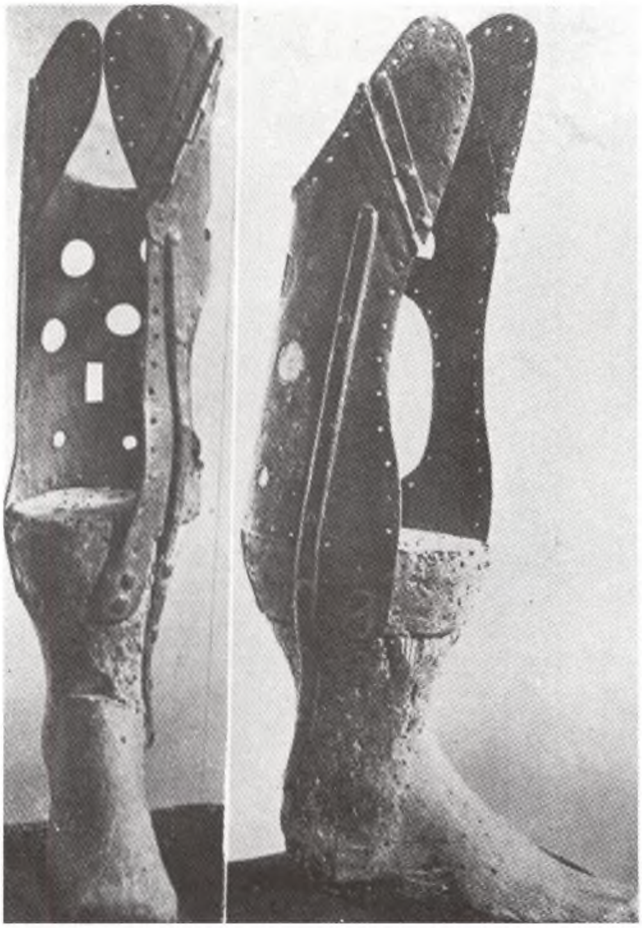

Figure 1.16 A composite below knee prosthesis for a congenital deformity. From Putti, *Historic Artificial Limbs*, figs. 4–5, 10–11.

Figure 1.17 The tomb of François II and Marguerite de Foix, designed by Michel Colomb and erected by Anne of Brittany in the cathedral in Nantes.

and lower extremities manufactured by makers of the beautiful articulated armor of the period (figures 1.13–1.16).

Several people with crippling disabilities played important roles in the political life of their time. Among the leaders of invading armies originating in central Asia one of the best known was Tamerlane (Timur i Leng, or Timur the Lame) (1336–1405). He was born in Transoxianna, south of Samarkand, and gradually consolidated his power through military and political success in tribal warfare. His conquests reached Moscow, Delhi, Damascus, Baghdad, and Ankara. While we have no accurate description of his deformity, he was said to have been very tall, with a large head crowned from childhood with white hair.

Figure 1.18 Close up of one of the figures identified by H. Winnett Orr as Anne. From Pierre Pradel, *Michel Colomb: le dernier imagier gothique* (Paris: Librairie Plon, 1953), pl. 9, pl. 12.

During World War I, there was an important base hospital for the American Expeditionary Forces at Savenay, near Nantes. The orthopedic surgeon in charge was Hiram Winnett Orr (1877–1956). On a visit to the cathedral in Nantes, he observed the memorial to Francis II of Brittany and Margret of Foix, which was designed by Colomb. Close observation of one of the four prominent supporting figures on the memorial suggests that she had a congenital dislocation of the hip. Further inquiry by Orr revealed that this figure was modeled on the person of Anne of Brittany (1477–1514), the daughter of Francis and Margret (figures 1.17 – 1.18). She was "small, flat chested and thin, and was even lame in one leg, an infirmity she managed to hide by means of pattens [shoe lifts]."[26] Anne was born in Nantes and inherited the duchy in 1488. She was married to Charles VII, the King of France, in 1491, and after his death was married to his successor Louis XII. She was an accomplished administrator who managed the affairs of the Duchy of Brittany in the best interests of her subjects. Orr was so impressed by the accomplishments of

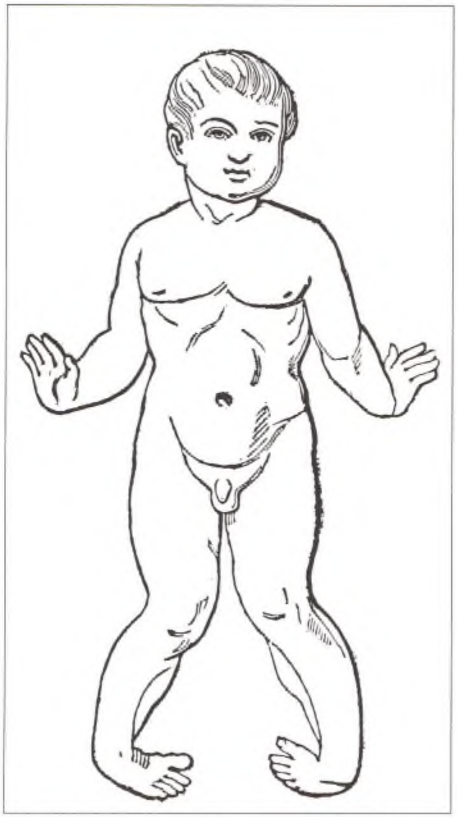

Figure 1.19 One of many figures from Paré's chapter on monsters and prodigies, this one suggesting arthrogryposis. From *Oeuvres complètes d'Ambroise Paré*, ed. J.-F. Malgaigne (Paris: J. B. Baillière, 1840), 3:26.

Figure 1.20 *A Procession of Cripples* by Hieronymus Bosch (1450–1516). From Eugen Hollander, *Die Medizin in der klassischen Malerei* (Stuttgart: Ferdinand Enke, 1903), fig. 66.

this "lame princess who became queen" that he became an expert on the facts of her life and times.[27]

Ambroise Paré (1510–1590) was a keen observer of his society and has left some interesting observations and illustrations of the cripples of his era, an example of which may be this first depiction of a patient with arthrogryposis (figure 1.19). In his chapter on monsters and prodigies he summarized his ideas on the causes of such deformities.

The causes of monsters are many:
The first is the glory of God;
The second is His anger;
The third is too large a quantity of semen;
The fourth is too small a quantity of semen;
The fifth is the imagination;
The sixth is narrowness or small size of the uterus;
The seventh is the carriage of the mother; i.e. being too fat, sitting too long with the thighs crossed, or too tightly compressing the abdomen;
The eighth is by a fall or a blow to the abdomen of the mother when the foetus is large;
The nineth is heredity diseases or accidents;
The tenth is by infection or by corruption of the semen;
The eleventh is by mixing of the semen;
The twelveth is by the guile of wicked and worthless beggars [such as comprachicos]*;*
The thirteenth is by demons or devils.[28]

Society before, during, and after Paré's time contained countless numbers of individuals afflicted by all kinds of crippling processes, a fact that can be appreciated by a glance at *A Procession of Cripples* by the Belgian painter, Hieronymus Bosch (1490–1516) (figure 1.20). The pictures painted by Diego Velázquez (1599–1660) of the dwarfs at the Spanish court are well known (figure 1.21). His contemporary Jusepe de Ribera (1591–1652) has left us this portrait of a youth with spastic hemiplegia (figure 1.22).

Alexander Pope (1688–1744) is, with the exception of Shakespeare, the most frequently quoted English writer.[29] His parents were both forty-six years of age when their sickly son was born and his life was "one long disease."[30] Pope's father was himself afflicted with a curvature of the spine. Whether Alexander's deformity was a congenital or idiopathic scoliosis is unknown. Although he became a successful writer, he was embittered because his deformity made him an object of ridicule by the woman he loved. He was described by Sir Joshua Reynolds as being "about four feet six high, very humpbacked and deformed"[31] (figure 1.23). He was unable to walk about without wearing a canvas corset. Nevertheless, he worked incessantly and made substantial contributions to English literature.

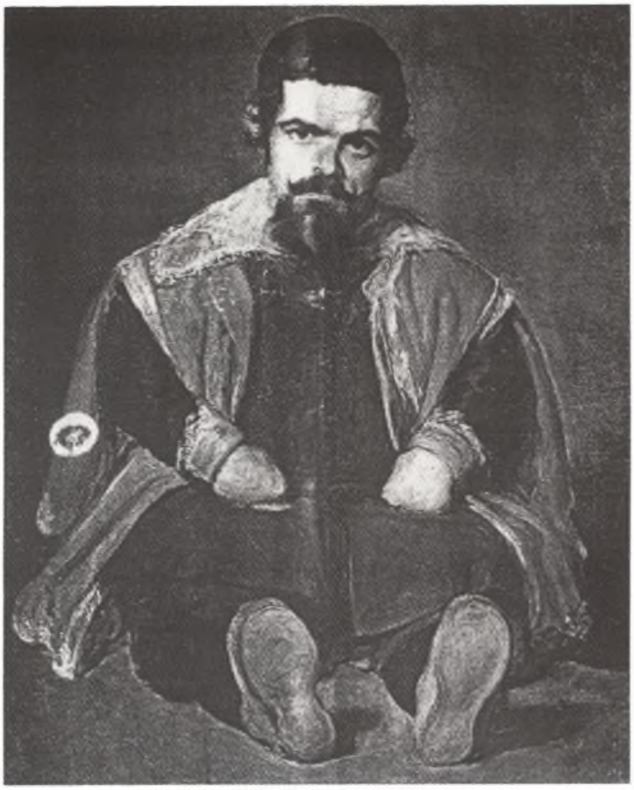

Figure 1.21 El Bufon Don Sebastian de Morra, one of the dwarfs in the Spanish court, painted by Diego Velázquez (1599–1660). With the permission of the Museo del Prado, Madrid.

Figure 1.22 A young man with spastic hemiplegia painted by Jusepe de Ribera (1591–1652), a Spanish painter who lived in Naples. From Eugen Hollander, *Die Medizin in der klassichen Malerei* (Stuttgart: Ferdinand Enke, 1903), fig. 61.

Figure 1.23 Alexander Pope in his old age, showing his small size and long kyphotic deformity. From the Courtauld Institute of Art, London.

Figure 1.24 Charles Maurice de Talleyrand de Perigord (1754–1838) from a sketch by Count D'Orsay made in London in 1831. From Joseph McCabe, *Talleyrand: A Biographical Study* (London: Hutchinson & Co., 1906), facing p. 358.

Charles Maurice de Talleyrand de Perigord (1754–1838) (figure 1.24) was the descendant of an old and powerful family. His father was a general and a member of the court of Louis XV. He was born in Paris and his parents hoped for a great career for him in the army. These hopes were thwarted when at the age of four he fell off a chest of drawers and suffered a crippling injury of his foot. Disqualified for military service, he was educated for the church. Active in church politics, his brilliance and connections resulted in his appointment as Bishop of Autun in 1789. He was a representative to the Estates General at the onset of the French Revolution. He resigned his bishopric in 1891 and was banned by the Pope for his anticlerical stands. After living as an émigré in London during the Terror, he returned to Paris and began working with Bonaparte. He became the grand chamberlain of the empire during the height of Napoleon's power. Changing sides quickly after the fall of Napoleon, he represented the restored Bourbons at the Congress of Vienna and later became the grand chamberlain in the court of Louis VIII. He was an enigma to his contemporaries and to historians. His own memoirs, written by a man who believed that "speech was given to man to disguise his thoughts,"[32] provide no explanations. His biographer seems to understand Talleyrand's situation best: "When you wish to trace the growth of the peculiar traits of Prince Talleyrand, you find the beginning in that fateful fall and dislocation of the foot."[33]

The Scottish novelist and poet Sir Walter Scott (1771–1832) (figure 1.25) has left an autobiographical account of the bout with poliomyelitis that left him crippled for life.

Figure 1.25 Sir Walter Scott, Bart. From J. G. Lockhart, *The Life of Sir Walter Scott, Bart.* (Edinburgh: Robert Cadell, 1837), frontispiece.

I showed every sign of health and strength until I was about eighteen months old. One night, I have been often told, I showed great reluctance to be caught and put to bed, and after being chased about the room, was apprehended and consigned to my dormitory with some difficulty. It was the last time I was to show much personal agility. In the morning I was discovered to be affected with the fever which often accompanies the cutting of the large teeth. It held me three days. On the fourth, when they went to bathe me as usual, they discovered that I had lost the power of my right leg. My grandfather, an excellent anatomist as well as physician, the late worthy Alexander Wood, and many others of the most respectable of the faculty, were consulted. There appeared to be no dislocation or sprain; blisters and other topical remedies were applied in vain.

When the efforts of regular physicians had been exhausted, without the slightest success, my anxious parents, during the course of many years, eagerly grasped at every prospect of cure which was held out by the promise of empirics, or of ancient ladies or gentlemen who conceived themselves entitled to recommend various remedies, some of which were of a nature sufficiently singular.

Figure 1.26 George Gordon, Sixth Lord Byron (1788–1824). From W. R. Bett, *The Infirmities of Genius* (New York: Philosophical Library Inc., 1952), facing p. 156.

The impatience of a child soon inclined me to struggle with my infirmity, and I began by degrees to stand, to walk, and to run. Although the limb affected was much shrunk and contracted, my general health, which was of more importance, was much strengthened by being frequently in the open air, and, in a word, I who in a city had probably been condemed to helpless and hopeless decrepitude, was now a healthy, high-spirited, and my lameness apart, a sturdy child — non sine diis animosus infans.[34]

Following the death of his great uncle in 1798, George Gordon (1788–1824) (figure 1.26), at the age of ten, succeeded to the title and estates, becoming George Gordon, Sixth Lord Byron. He was born with what now appears to be a spastic paraplegia.[35] His whole life was colored by what Thomas Macaulay (1800–1859) called "the bad fairy's bundle." He was rejected by his mother, who once called him "a lame brat," and by his first love, whom he accidentally overheard saying to her maid, "Do you think I could care for that lame boy?" Because of his literary gifts, Byron was considered by his contemporaries to be the foremost poet of his day and a very romantic figure; he was much in the public eye. In 1816 he left England, never to return, dying in Greece during the Greek revolution against the Turks.[36]

Byron expressed his feelings regarding his mother and his deformity in one of his plays, *The Deformed Transformed.*

Part 1, Scene 1

Enter: Arnold and his mother Bertha

Bert: Out, hunchback!

Arn: I was born so, mother!

Bert: Out, thou incubus! Thou nightmare! Of seven sons the sole abortion!

Arn: Would that I had been so, and never seen the light!

Bert: I would so too![37]

Figure 1.27 Tom Thumb posing between two grenadier guards in London. From Raymond Fitzsimmons, *Barnum in London* (New York: St. Martin's Press, Inc., 1970), facing p. 21.

There is no question that Byron was one of many cripples who fall into the group Thoreau had in mind when he wrote, "The mass of men lead lives of quiet desperation."[38]

Persistent folk tales of trolls who lived under bridges in northern Europe and the little people of Ireland attest to the continuing fascination of the public with dwarfs. In real life the most famous midget was Charles Sherwood Stratton, better known as General Tom Thumb (1838–1883), who was discovered by P. T. Barnum in Connecticut and became known throughout the world, even being received by Queen Victoria (figure 1.27). The fairy tale of Tom Thumb, or *Le petit pouce*, was in a collection of

Figure 1.28 Kaiser Wilhelm II with the painter Adolph Menzel, called "die kleine Excellenz," viewing the portraits of some grenadier guards in antique uniforms. From Hans Wurtz, *Zerbrecht die Krucken* (Leipzig: Leopold Voss, 1932), facing p. 16.

Figure 1.29 Dame Agnes Hunt. From Agnes Hunt, *Reminiscences* (Shrewsbury: Wilding & Sons, Ltd., 1935), frontispiece.

half-forgotten folk tales gathered together by Charles Perrault (1628–1703), a French savant, to amuse his children.[39] In 1939, with the production of the *Wizard of Oz*, the munchkins, played in the movie by achondroplastic dwarfs, joined the legendary group around Snow White, immortalized by Walt Disney as Doc, Sleepy, Dopey, Happy, Grumpy, Sneezy and Bashful. Dwarfs fascinate children because they are adults of their own size. They continue to hold the interest of adults because they are peers who never grew up. Above all dwarfs are fascinating because of the universal interest in the unusual.

In Berlin on the night of January 26, 1859, Victoria Louise, the daughter of Queen Victoria, and the wife of the Crown Prince of Prussia, delivered her first child after a very difficult breech delivery.[40] While no one could dispute that the baby had suffered a fracture of the left humerus and a brachial plexus injury during extraction, whether or not the child had suffered any brain damage as a result of anoxia was never established. Twenty-nine years later, he became Wilhelm II, the German emperor or *Kaiser*. In spite of his crippled arm he had served in the First Foot Guards and the Guard Hussars (figure 1.28). His blustering speeches were considered to be an expression of his unstable personality. Interestingly enough, an analyst writing about the personality and behavior of the Kaiser in 1915 never mentioned the possibility that his deformity may have affected any of his attitudes.[41]

Agnes Gwendolyn Hunt (1867–1948) (figure 1.29) was one of eleven children of a well-established English family based in Shropshire.[42] At the age of ten, as a result of an acute hematogenous infection of the upper end of the femur, she became permanently crippled and was troubled with recurrent abscesses and drainage from the region. She maintained a high level of physical activity in spite of her handicap. She spent an adventurous adolescence in Australia and Tasmania, returned to England, and after a great deal of difficulty, obtained a position as a student nurse at the Royal Alexandra Hospital in London. The honorary consulting surgeon at the hospital was Hugh Owen Thomas, and it is noteworthy that Hunt, working at this hospital, instituted the first program integrating fresh air as an important part of the treatment program for patients with chronic tuberculous infections. After obtaining her nursing certificate, she served for eleven years as a district nurse in rural areas. With the encouragement of her mother she organized a convalescent home for the Salop Infirmary and opened the Baschurch Home in north Wales on October 1, 1900. Here she put into practice the fresh-air treatment with her patients. In 1903, because of a recurrence of her infection, she consulted Robert Jones (1858–1933) at 11 Nelson Street, Liverpool, who arranged for her treatment, which consisted of several operations and a long period of immobilization. She interested Jones in her little hospital and he came to

Figure 1.30 Stalin, Roosevelt, and Churchill, the three allied leaders in the war against Hitler, at the Tehran Conference, November–December 1943. Each or these men achieved success, despite a serious crippling injury or disease. U.S. Army Photograph.

visit. This visit resulted in his continuing involvement in what eventually became the Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry. In addition to her hospital work, she began a follow-up program for discharged patients and later a vocational program, the Derwen Cripples Training College. Because of her lifelong devotion to the improvement of the lot of the crippled and handicapped in her society, she was honored by the British government, becoming Dame Agnes Hunt.

The allied effort against Hitler in World War II was directed by three very powerful men, all of whom suffered from the effects of crippling injuries or diseases (figure 1.30). Joseph Stalin (1879–1953) was a battered child, the victim of repeated beatings by his father. The most serious injury was an open supracondylar fracture of the left humerus, which healed with shortening and limitation of motion in the elbow and some signs of a Volkmann's ischemic contracture.[43] Franklin D. Roosevelt (1882–1945) had a very active life style until the age of thirty-one, when an attack of poliomyelitis resulting in paralysis of both lower extremities left him confined to a wheelchair for the rest of his life. Winston Churchill (1874–1965), as a young cavalry officer, was a superb polo player. His career in this arena was ended as a result of a dislocation of his right shoulder that occurred while his regiment was landing in Bombay.[44] This dislocation, which became recurrent, limited his performance of certain activities the rest of his life.

The continuing fascination of the public with cripples and the theme of crippledom can be measured by the success of the plays, *The Elephant Man* and *A Day in the Death of Joe Egg*, and novels such as W. Somerset Maughams's *Of Human Bondage*, whose protagonist Phillip Carey had a clubfoot.[45]

Not all cripples could overcome their handicaps and lead meaningful lives. Many needed help when little, if any, was available. It was in response to this need that the specialty of orthopedics developed. Its history is a recital of the names of compassionate and altruistic physicians who dedicated their lives to the improvement of the world of cripple, or crippledom.

Notes

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3. C. S. Bartsocas, "Hephaestus and Clubfoot," *J Hist Med Allied Sci* 27(1972): 450–51.

4. Homer *The Odyssey*, trans. Robert Fitzgerald (New York: Garden City Pub., 1930), 144–49.

5. J. Warkany, *Congenital Malformations* (Chicago: Yearbook Medical Pub., 1971), 6–20.

6. Leviticus 21:18–19.

7. Genesis 30:25–43.

8. John Boswell, *The Kindness of Strangers* (New York: Pantheon Books, 1988).

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10. *The Dialogues of Plato*, trans. B. Jowett (New York: Random House, 1937), 1:722

11. G. H. Payne, *The Child in Human Progress* (New York: G.P. Putnam's Sons, 1916), 242–44.

12. F. H. Garrison, *Abt-Garrison History of Pediatrics* (Philadelphia: W.B. Saunders Co., 1965).

13. As in his previous novels, *Notre Dame de Paris* (*The Hunch Back of Notre Dame*) and *Le Roi s'amuse* (*The King's Fool*), which became the libretto for Verdi's *Rigoletto*, Victor Hugo treated his crippled and deformed characters with sympathy and humanity; Victor Hugo, *The Man Who Laughs*, trans. William Young (New York: D. Appleton & Co., 1889), 13–20.

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15. Ilza Veith, "The History of Medicine Dolls and Foot-Binding in China," *Clio Med* 14(1980): 255–67.

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18. M. Ruffer, "On Dwarfs and Other Deformed Persons in Ancient Egypt," in idem, *Studies on the Paleopathology of Egypt*, ed. R. L. Moodie (Chicago: University of Chicago Press, 1921), 35–48.

19. Ruffer, "Dwarfs," 35–48.

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21. 2 Samuel 4:4, 9:1–13.

22. F. J. Bove, *The Story of Ergot* (Basel: S. Karger, 1970).

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CHAPTER TWO

The Origin of Orthopedics

In the beginning was the word, and the word was l'orthopédie.

THE HISTORY OF ORTHOPEDICS as a medical and scientific discipline begins in the middle of the eighteenth century. Although deformities and crippling diseases had been treated empirically for thousands of years, sometimes with success, a special event marked the birth of this new medical specialty. This event was the publication of a small monograph by Nicolas Andry (1658–1742) in Paris in 1741. Andry's book, *L'Orthopédie, ou l'art de prévenir et de corriger dans les enfans, les difformités du corps*,[1] was not directed primarily toward physicians, but instead was meant for parents and individuals concerned with raising children. It was similar to two popular books on child rearing written by his contemporaries: *Paedotrophia*, by Scaevole de Sainte-Marthe (1536–1623), and *Callipoedia*, by Claude Quillet (1602–1661).[2] Just as the terms *paedotrophia* and *callipoedia* took their origin from the Greek words for *child-nurture* and *beautiful child*, Andry derived the term *orthopédie* from the Greek words meaning *straight child*. The frontispiece of Andry's book is an allegorical scene, a seated mother surrounded by three children and holding in her hands a rule upon which are inscribed the words *haec est regula recti* (this is the rule for straightness) (figure 2.1). The contents of the book are well summarized in the title *Orthopaedia: or the Art of Correcting and Preventing Deformities in Children by Such Means as May Be Put into Practice by Parents Themselves and All Such as Are Employed in Educating Children.*[3]

The works of Sainte-Marthe and Quillet have been forgotten. The book by Nicolas Andry could have joined them in oblivion very easily except for two very fortunate circumstances, one semantic and one pictorial. The term *orthopédie* coined by Andry became attached to an important surgical specialty that deals with

Figure 2.1 The frontispiece from Nicolas Andry, *L'Orthopédie* (Paris: la veuve Alix, 1741).

the diagnosis and treatment of diseases and injuries of the locomotor system, and one of the illustrations in the book, that of the crooked tree (figure 2.2), was adopted throughout the world as the symbol of this specialty.

In the chapter entitled "The Legs Crooked," Andry says:

When a child begins to walk, while his legs are too weak for his body, you will observe him try to prop his knees, the one against the other, to support himself. In this case you ought not to allow him to walk, but make him fit as much as you can, 'till his legs become stronger; otherwise they will begin to grow crooked by degrees; afterwards they will bend in the form of an arch; and at last will become so deformed, as it will be impossible to help them.

The sooner then that you hinder a child to walk, when you observe his knees begin, the least in the world, to incline inwards, it will be so much the better; and if from neglecting this precaution, the leg is already crooked, you must apply, as soon as possible, a small plate of iron upon the hollow side of the leg, and fasten it about the leg with a linen roller. This roller must be made tighter and tighter every day, 'till it compresses sufficiently the part that bunches out; and that this compression may not hurt it, you must put a large compress under the bandage, on that part of the leg. In a word, the same method must be used in this case for recovering the shape of the leg, as is used for making straight the crooked trunk of a young tree.[4]

A progenitor of Andry was Felix Wurtz (1518–1574), whose book *Ein schoenes und nutzliches Kinderbuchlein*, published in 1616, is considered to be the first book dealing with pediatric surgery.[5] He discusses the care of clubfeet and other deformities and in his comments upon treatment by bandaging says, "The Child groweth like a twigg, according as it was tyed."[6]

The figure of the crooked tree tied to the straight stake beautifully illustrates what Alexander Pope (1688–1744) had in mind when he wrote, "Tis education forms the common mind: Just as the twig is bent, the tree's inclined."[7]

An important basic orthopedic principle is embodied in the figure of the tree and in Pope's rhyme. The bone is not an inert, calcified, fibrous material. It is a growing, plastic, dynamic structure with an active metabolism that responds to a wide variety of stimuli, and is as truly "alive" as any other tissue in our bodies. There is not an area of interest in the entire spectrum of orthopedics that can ignore this basic principle, and indeed, only a few exist that have not built upon it.

Nicolas Andry was born in Lyon. His first course of study was for the priesthood.[8] It was not until later that he studied medicine at Rheims and Paris, obtaining his medical degree in 1697 at the age of thirty-nine. Four years later he became a professor in the Collège de France and a member of the editorial board of the *Journal des savants*, the most important scientific journal of the

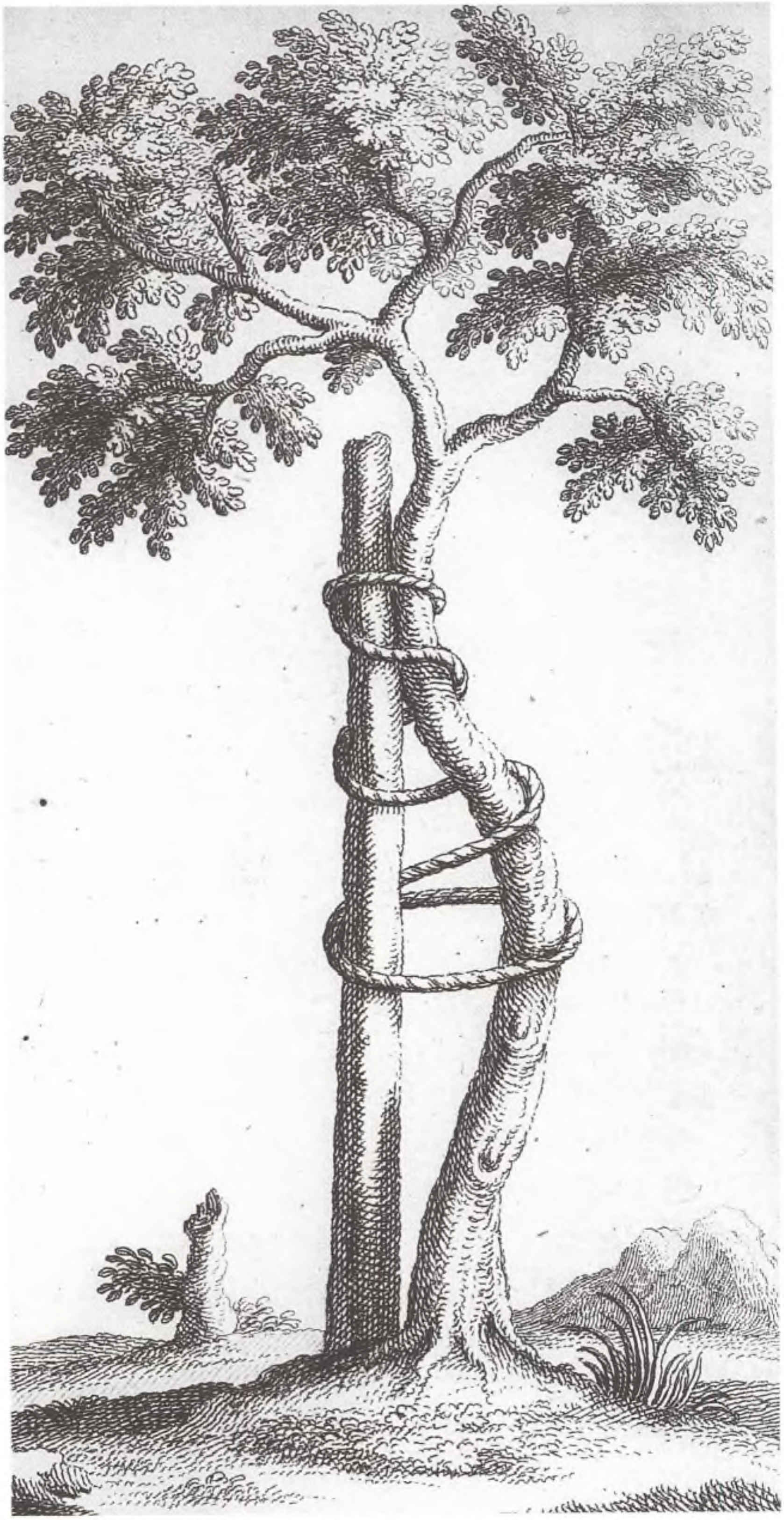


Figure 2.2 The crooked tree tied to the straight stake, which has become the logo of the specialty of orthopedics throughout the world. From Andry, *L'Orthopédie*, vol. 1, facing p. 211.

Figure 2.3 Jean-André Venel (1740–1791). From B. Valentin, "Jean-André Venel (1740–1791) der Vater der Orthopädie," *Sudhoff's Archiv* 40(1956): following p. 312.

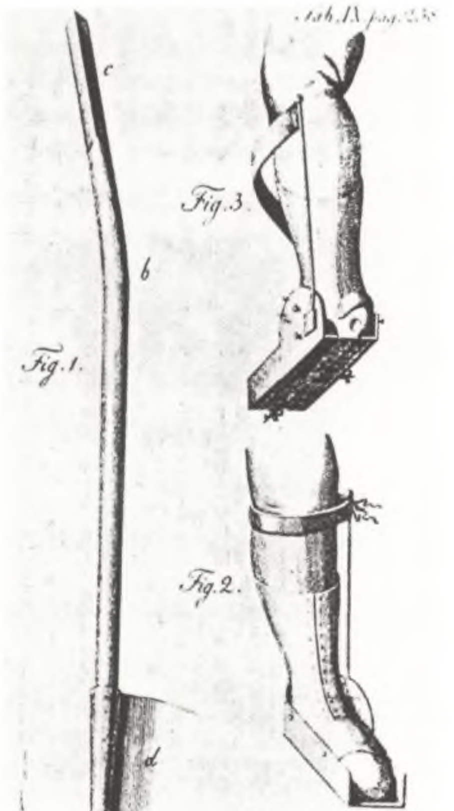


Figure 2.4 The *sabot de Venel*, an active brace for the correction of clubfeet. From Valentin, "Jean-André Venel," following p. 312.

day. In 1724 he was made dean of the Faculty of Medicine in Paris and in this role waged a long and acrimonious battle to control the activities of the surgeons. No authentic portrait of him is known to exist.[9]

The emphasis of Andry's book is in the classical tradition of *mens sana in corpore sano* (a sound mind in a sound body), for he writes:

It is not only allowable to take care of the Gracefulness of the Body, but this care, while it is confined within certain Bounds which Reason prescribes, and which every body is well acquainted with, ought to be enjoined. We are born for each other, and ought to shun having anything about us that is shocking; and even though a Person should be left alone in the World, he ought not to neglect his Body so as to let it become ugly; for this would be contradicting the intention of the Creator.[10]

Andry proposed to accomplish this end by means of exercise.

Of all the Methods proper for preserving Health, and for preventing, and even curing a great number of Diseases, there is none equal to moderate Exercise. It at the same time rouses the natural Heat, dissipates the superfluous Humours, corrects those that are acrid, gives Agility to the Muscles, strengthens the Nerves and Joints, opens the Pores, and assists the Perspiration. Hence the whole Body must be strenthened, [*sic*] *the Senses rendered quicker, Respiration more free, the Heart strong and vigorous, and the chylopoetick Viscera perform their Offices more readily.*[11]

He extols the value of regular exercise such as walking and all of the active games and sports of children, youths, and adults in the same manner as Girolamo Mercuriali (1530–1606) had done in his book on gymnastics published in 1569.[12] His emphasis on "the body beautiful," fitness, and exercise gives his book a very modern tone. In the great debate regarding the relative value of motion versus rest in the treatment of disease, Andry stands strongly on the side of motion.

It is important to point out that Andry is remembered, not for making any great discovery or contribution to the specialty for which he provided a name, but because by providing this name, he focused attention upon a group of long-neglected crippling conditions, which in the two hundred years following his death would become a significant area of specialization.

The first physician to approach the treatment of crippled children in a systematic fashion with attention to their social as well as their medical needs in an institutional setting was Jean-André Venel (1740–1791)[13] (figure 2.3). Bruno Valentin considered him to be "the father of orthopedics."[14] Venel was born in Morges, Switzerland, on the shore of Lake Constance near Lausanne. He was the descendant of a French Huguenot family that had fled

Figure 2.5 The system of traction used by Venel for the treatment of back deformities during the night. From Valentin, "Jean-André Venel," following p. 312.

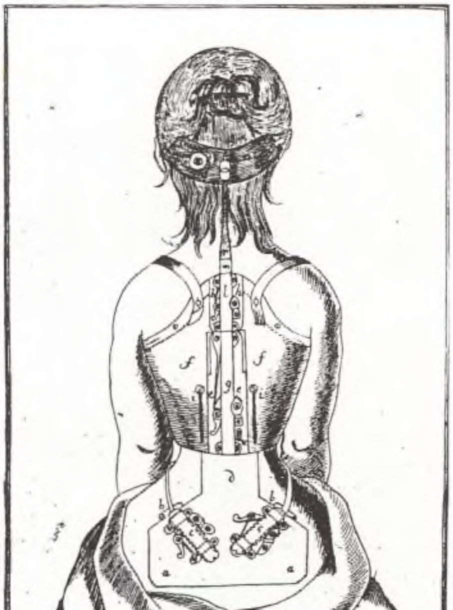


Figure 2.6 The back brace used by Venel during the day. From Valentin, "Jean-André Venel," following p. 312.

the religious wars in France during the late seventeenth century. His father, who died when Venel was only seven years old, was a barber-surgeon. At the age of sixteen Venel was apprenticed to a local surgeon with whom he remained for six years before enrolling in the Royal College of Surgeons in Montpellier. He left the college without a degree after only a year, probably because of lack of funds. He married and entered practice in Orbe, Switzerland, a small town near the French border between Lakes Geneva and Neuchâtel. After two years in practice, he spent a year in Paris and Strasbourg in the study of obstetrics. Returning to Orbe, he practiced there for four more years before becoming the physician of a Polish nobleman in whose service he remained five years. He subsequently returned to Orbe where he opened a school for midwives and wrote two books, one on midwifery, the other on medical advice for young women.

Venel became interested in orthopedics when one of the local ministers brought his seven-year-old son in for examination because of bilateral asymmetrical foot deformities, probably caused by poliomyelitis. The boy remained in Venel's home under his care for more than a year and a good correction of the deformities was obtained. In 1780 Venel took over a ruined cluster of buildings in Orbe called l'Abbaye and slowly restored them, developing the first orthopedic institute. The institute had a hospital facility, an occupational workshop, a therapeutic bath, a classroom for the patients, and a brace shop. When a patient was admitted, a plaster mold of his deformity was made that was compared with a similar mold made at the time of his discharge. The initial mold was used as a pattern upon which any apparatus was constructed. Venel's treatment, lasting long periods of months and even years, consisted of warm baths, massage, manipulation, stretching, and the use of "active" splints. The *sabot de Venel* (figure 2.4), used to correct clubfeet, relied on the constant tension of the lateral side bar for its effectiveness. For the treatment of scoliosis, the patients remained recumbent in traction during the night, but were allowed to be ambulatory in a brace during the day (figures 2.5 – 2.6).

William Coxe, an English traveler, left a good description of the institute in a letter to his friend William Melmoth.

> *Mr. Venel, an eminent surgeon of this town* [Orbe], *has formed, under the protection of the government of Berne, an establishment which well deserves the attention of the humane and curious traveller. It is an infirmary for the reception of those objects, who are born with distorted limbs, or have by accident acquired that misfortune.*

> *The children are lodged and boarded in the house, under the care of his assistant, who charges himself with all the detail of housekeeping, and instructing those, whose age renders it requisite, that their education should not be neglected.*

Figure 2.7 Robert Chessher (1750–1831), the first British orthopedist. From R. T. Austin, *Robert Chessher of Hinckley* (Leicestershire County Council Libraries and Information Service, 1981), frontispiece.

Mr. Venel's skill in improving and simplifying those machines necessary for his purpose, has been sufficiently attested by the various cures which he has performed that way.

Though he chiefly confines his attempts to infants and children, yet he has performed several cures on adult persons. His most efficacious remedy is a machine which he has invented to embrace the patients limbs when in bed, and which is so contrived as to act without disturbing their rest. Ingenious as his method is, yet he acknowledges, that much of his success depends on the mild treatment of the patients, and on having them continually under his inspection. I was convinced indeed of the mildness of his treatment, by observing several of these children, from four to ten years of age, crawling about the ground, and diverting themselves with great cheerfulness, although cased up in their machinery.[15]

Following Venel's untimely death from tuberculosis in 1791, the institute, which had never been in good financial condition, floundered under the management of his surviving relatives and was finally closed in 1820.

While Venel published some papers and reports, he never completed a major exposition of his ideas and methods based on his experience. Valentin has provided the best review of what is available.[16] Venel had great talent and inventiveness in the construction of braces and splints. His personality was warm and he showed concern and love for his patients, who in turn showed him affection.

While Venel was using an intramural program for the treatment of patients with deformities, in Hinckley, England, Robert Chessher (1750–1831) (figure 2.7), the "father of English orthopedics," was using an extramural program with the same goals.[17] Chessher was born and lived almost all of his life in Hinckley, a small community midway between Birmingham and Leicester. His father died when he was a child and his mother then married a local surgeon. After obtaining a basic education locally, Chessher went to St. Georges Hospital in London for a time, eventually obtaining his medical degree in Aberdeen, Scotland. Initially he was interested in obstetrics, but after his stepfather's death, he became financially independent and decided to concentrate on the treatment of patients with deformities. Over a period of years, Chessher devised a system that provided for the careful and regular supervision of his patients as outpatients. Chessher was very ingenious and invented appliances, machines, and splints to suit the needs of his patients, employing several mechanics and brace makers to fabricate them. A most useful contribution to the treatment of fractures was his invention of the double-inclined plane, allowing the surgeon to realize the goal of Pott, which was to treat the fractured femur with the hip and knee flexed, without requiring the patient to lie on his side. He also developed a

Figure 2.8 The layout of the grounds of Delpech's institute. From Delpech, *De l'Orthomorphie* (Paris: Gabon et Cie, 1823), pl. 48.

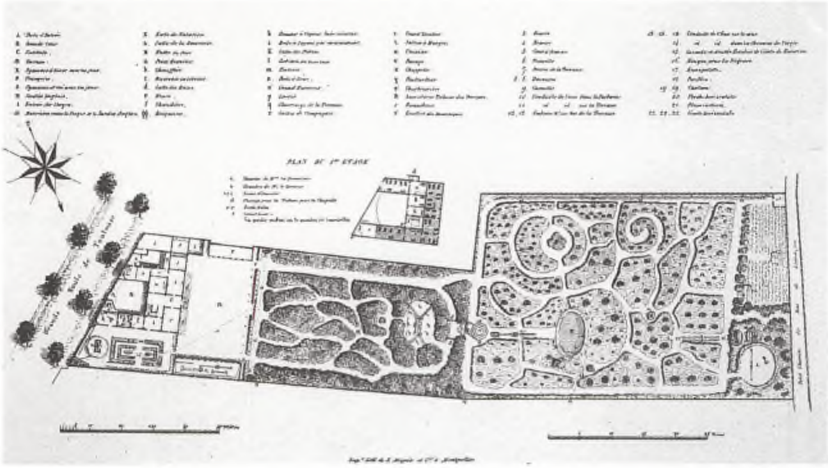
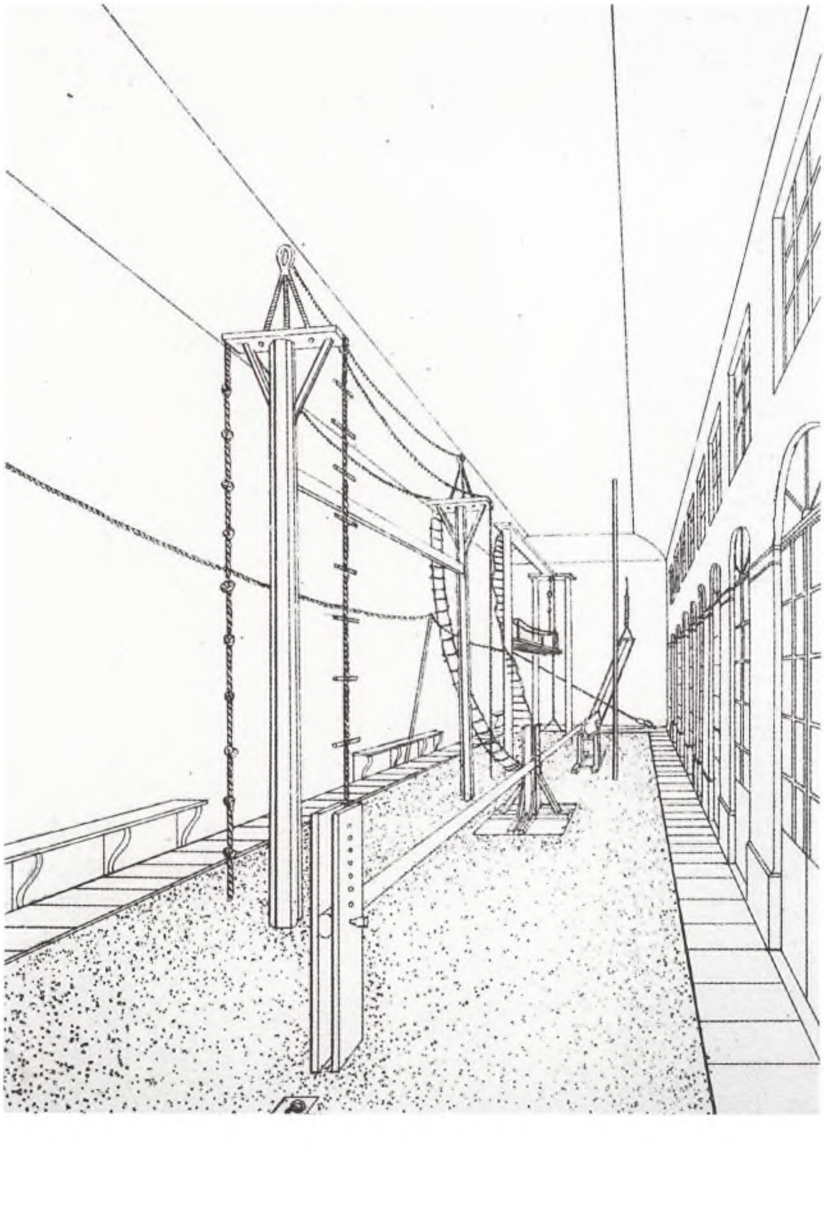


Figure 2.9 An indoor exercise area in the institute. From Delpech, *De l'Orthomorphie,* pl. 51.



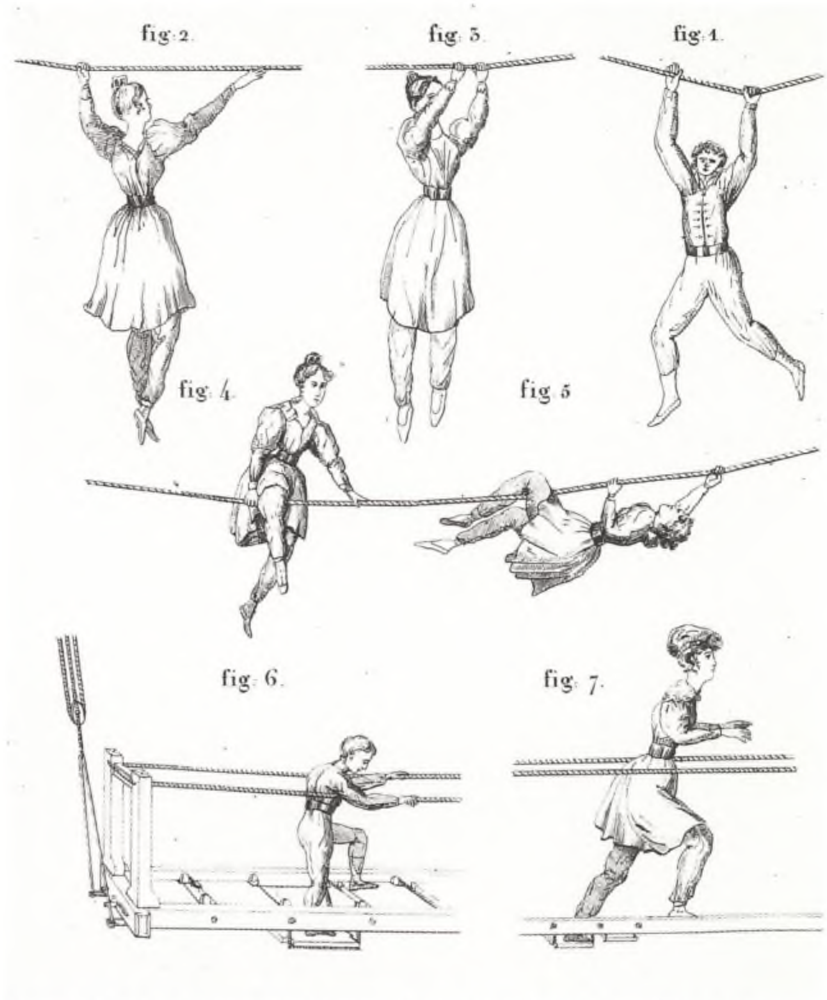


Figure 2.10 Working out with ropes. Note the costumes designed by Delpech to permit motion and preserve modesty. From Delpech, *De l'Orthomorphie*, pl. 66.

spinal brace, *Chessher's collar*, which consisted of a carefully fitted pelvic band and shoulder straps, to which was attached a mast from which the head was suspended by slings under the chin and occiput. No active extension or traction resulted, the brace functioning only to decrease the weight borne by the spine. In addition to the use of apparatus, Chessher depended upon massage and both passive and active assisted motion, sometimes provided by machines, to obtain his results.

As Chessher's experience and reputation grew, so did his patient population. At one time as many as two hundred patients from other areas boarded in the town and received treatment under his care. This was an economic boon to a town of only forty-five hundred people. In spite of his efforts he was never able to establish a hospital for his patients. Like Venel, he had no successors. His methods and results were not carefully recorded, and we know little about him except through secondary sources.

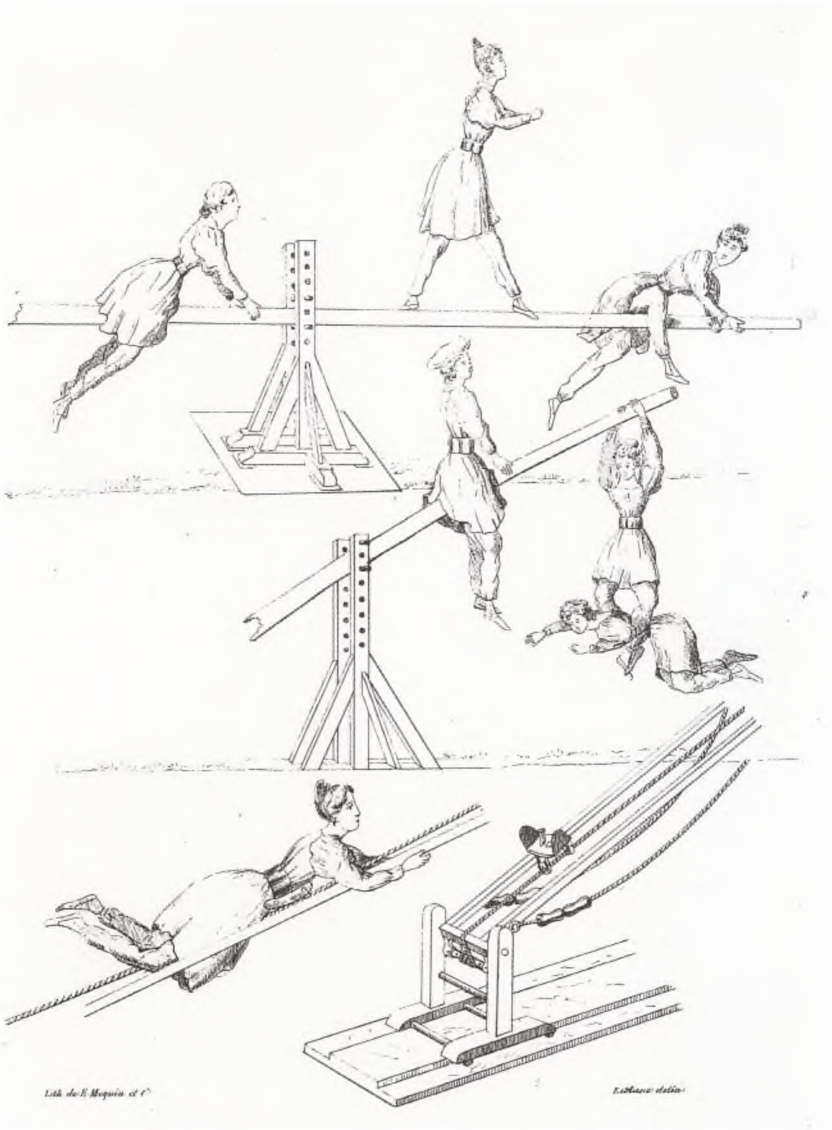


Figure 2.11 Working out on the balance beam. From Delpech, *De l'Orthomorphie*, pl. 67.

Interest in the institutional treatment of patients with diseases and deformities of the back and extremities continued to grow. One of the most unique and appealing institutions of its sort, as well as the first to appear in France, was founded by Jacques-Mathieu Delpech (1777–1832) in Montpellier in 1825. Delpech was the first to establish the true nature of Pott's disease, contending that *mal du Pott* should be called *affection tuberculeuse des vertèbres.* He was thus able to discriminate between patients with tuberculosis of the spine and those with idiopathic scoliosis, poliomyelitis, and other nontuberculous diseases of the spine. It is for this latter group that his institute was founded. Located on a small tract of land outside of Montpellier to take advantage of the fresh country air, its buildings contained facilities for housing and caring for the patients as well as an enclosed gymnasium. Outside was a garden, which contained a maze of paths connect-

Figure 2.12 The "teeter-totter." From Delpech, *De l'Orthomorphie*, pl. 57.

ing various exercise areas. The treatment of the spinal disorders was based on exercise and gymnastics. To ensure that the exercises could be performed freely and with proper decorum, Delpech designed special costumes for young men and women. Most patients remained as residents in the institute for one or two years (figures 2.8–2.13)

Delpech (figure 2.14) was born in Toulouse, where he began his medical studies at the age of twelve under the aegis of Alexis Larrey, the uncle and first teacher of J. Dominique Larrey. When he was fifteen years old he enlisted as a surgical dresser in the French army, in which he served for five years. After resuming his studies, he received a degree from the medical school in Montpellier in 1801. This was followed by some years of postgraduate study in Paris, after which he returned to Montpellier. As a result of a competitive examination, he was made professor of surgery and chief surgeon of the Hôpital St. Éloi in Montpellier in 1812. By training and by instinct he was a surgeon. His first important paper dealt with hospital gangrene, a condition he had seen and treated frequently both in the army and in civilian practice.[18] He

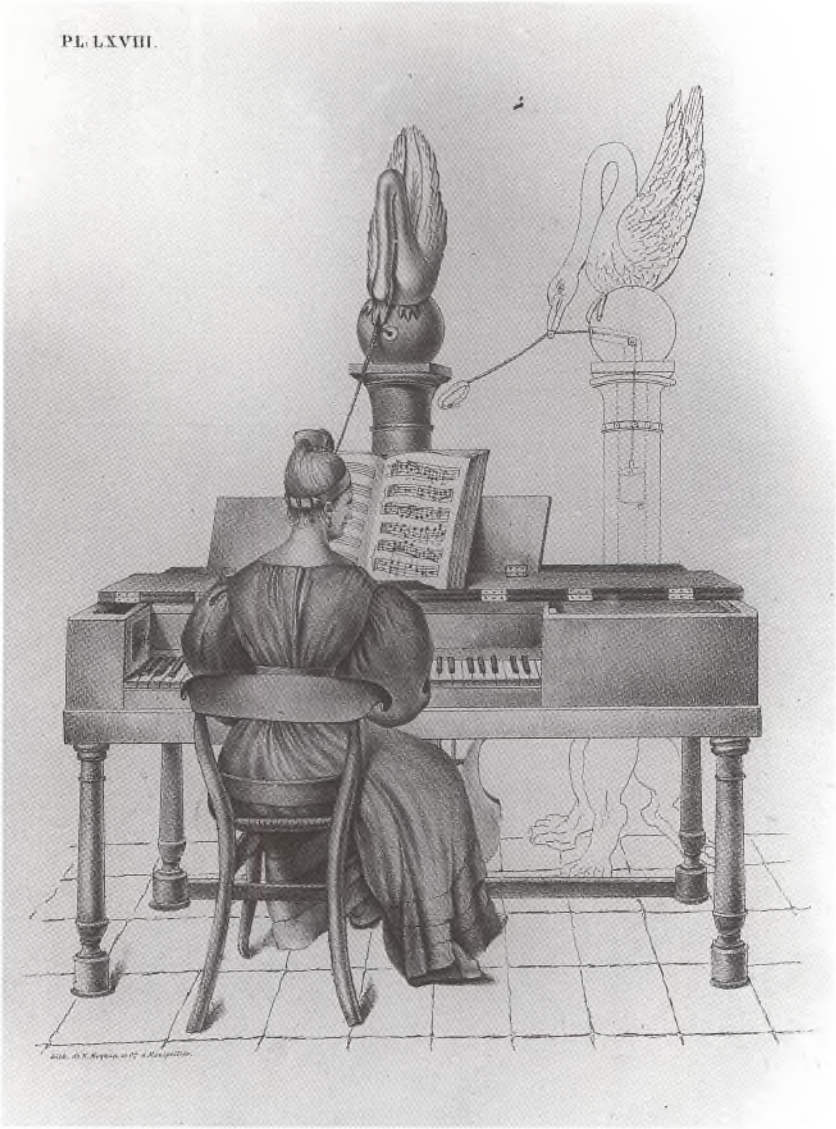


Figure 2.13 This bizarrely ornamented postural aid for pianists is one of several devices designed by Delpech.

Figure 2.14 Jacques-Mathieu Delpech (1777–1832). Courtesy of the New York Academy of Medicine Library.

was one of the first surgeons to point out the danger of spreading infection as a result of direct contact with pus, dirty dressings, and unclean hands.[19]

Delpech described his methods and his institute in his book, *De l'orthomorphie*, published in 1828.[20] Unfortunately we do not know whether or not his program attained his goals. On October 29, 1832, while returning to the institute from the city, Delpech was shot by a deranged patient on whom he had operated for a hydrocele. The bullet passed through his chest destroying the arch of the aorta, and he died instantly. The coachman, supporting Delpech in his arms, was also fatally shot. The horses galloped off with the carriage and delivered the bodies to the institute, which was closed shortly afterward. All that remains of Delpech's institute are the charming lithographs of young people engaged in therapeutic exercises in a sylvan setting.

Figure 2.15 The apparatus used by Delpech after performing the tenotomy to slowly correct the equinus deformity.

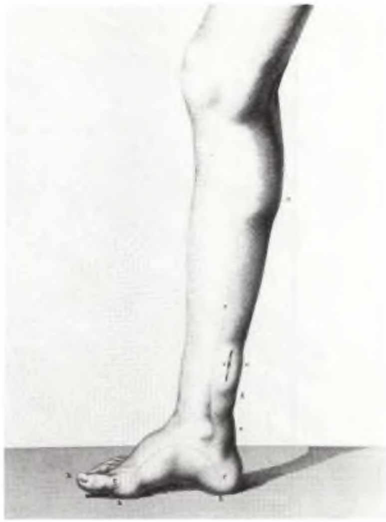


Figure 2.16 The appearance of the patient three years after the operation. It appears that the wound was larger and that the tendon was divided more proximally than described. The correction was excellent. From Delpech, *Chirurgie clinique de Montpellier* (Paris: Gabon et Cie., 1823), pls. 9 – 10.

The legacy of Delpech is much more than a series of interesting pictures, however. He was one of the first surgeons to attempt to correct deformities by surgical methods, and his success gave a new dimension to the practice of orthopedics. In a collection of papers from his clinic published in 1823 is one entitled *Considérations sur la déformité appelée pied-bots*, which describes the treatment of seven patients with clubfeet.[21] The first six were treated with the application of the usual types of apparatus with varying degrees of success. He recounts all of the complications and difficulties, including noncompliance of the family with these prescribed regimens. The seventh patient, a boy of nine with a severe equinus deformity, had undergone treatment with braces without benefit. Drawing upon his experience with patients with spontaneous ruptures of the Achilles tendon that had healed with the formation of material between the ends of the tendon, Delpech considered the possibilty that such a healing process would occur if the tendon were surgically divided.[22] He decided to divide the tendon completely close to its insertion in such a way that air did not enter the wound. The foot would then be placed in an apparatus in its deformed position until the tendon had healed, and then be slowly brought up to a right angle with the leg. After discussing the procedure with the boy's parents, he performed the operation on 16 May 1816.[23] With the patient lying on his abdomen, two small wounds were made with a bistoury on either side of the Achilles tendon. A second sharply

Figure 2.17 Georg Friedrich Louis Stromeyer (1804–1876). From J. Gerliff, "The Development of Quarantine," *Ciba Symposium* 2(1940): 566–80.

curved knife was then used to divide the tendon transversely. Fortunately for the patient, the procedure was not very painful. After dividing the tendon, the foot could be brought up to a right angle with the leg easily, but after applying a small dressing the foot was bound in an apparatus in its original position (figures 2.15 – 2.16) The wounds healed slowly. On the tenth postoperative day a small hematoma was evacuated; two days later, a small amount of pus. On the twentieth postoperative day there was still a slight serous drainage. By the twenty-seventh day, the wounds were well healed and there appeared to be good adhesion between the ends of the tendon. Correction of the deformity was then commenced and at the end of a month was complete. After the description of this case, Delpech discusses the role of tendons and muscles in the etiology of various deformities and the potential value of tenotomy and myotomy, concluding, "We believe that today the operation is practical and can be applied in all areas where the tendons oppose the normal position of the extremities and are the cause of the deformity."[24]

It is important to understand that Delpech did not describe simply the operation of subcutaneous tenotomy of the Achilles tendon, but the whole genus of subcutaneous tenotomies and myotomies of which heel cord tenotomy was but one species. The operation was based on his conception that tendon and muscle contractures were the basic cause of the deformities and that by releasing the contractures, prevention of further deformity, or partial or complete correction of the deformity, could be achieved.

His operation was not well received by his surgical colleagues. In a footnote to a discussion of the treatment of clubfeet published in 1829, he comments:

> *The editor of a journal in the capitol* [Paris] *refused to insert our rebuttal to his criticism that we had proposed this operation "seriously". He can hardly have read the history of the case we have published to see that we had not only proposed the procedure, but carried it out successfully. The editors of the* Revue médicale *decided that this operation was a mistake, but they at least discussed its merits.*[25]

Because of the opposition of his peers, Delpech stopped performing any operations of this type.

While the crowd hung back, Guillaume Dupuytren (1777–1835), the surgical leader of Paris and a friend of Delpech, did not. On 16 January 1822 he performed a subcutaneous myotomy of the sternocleidomastoid muscle on a twelve-year-old girl with a severe torticollis.[26] This case was widely reported on the continent as well as in England.[26]

A young German surgeon in Hanover revived Delpech's operation in 1833. Georg Friedrich Louis Stromeyer (1804–1876) (figure 2.17) came from a long line of teachers and physicians in

Figure 2.18 William John Little (1810–1894). From *J Bone Joint Surg* 31B (1949): facing p. 123.

Hanover, where he was born and raised. After finishing his studies at the surgical school in Hanover, he continued his education in Göttingen and Berlin. He then traveled extensively in France and England and also visited Vienna. In 1828 he returned to Hanover and established a small orthopedic clinic. It was here two years later that he saw a nineteen-year-old male student with an equinus deformity of the left foot, probably the result of poliomyelitis. Previous nonoperative treatment had been complicated by ulceration and osteomyelitis of the fifth metatarsal; this treatment was abandoned. Using the publications of Delpech as the basis for a surgical approach, on 28 February 1831 Stromeyer carried out a subcutaneous tenotomy of the Achilles tendon. The postoperative treatment consisted of placing the foot in an apparatus in the deformed position and maintaining this position until the wound healed. There were no complications in wound healing, and on the tenth day correction of the equinus was begun. Complete recovery was delayed by the presence of ulcerations on the foot, brought on by the previous treatment, and by persistent swelling. However, a good functional result was eventually obtained. Encouraged by this experience, Stromeyer carried out a second operation, this time on a thirty-two-year-old man with an equinus deformity that also was a result of poliomyelitis. The procedure went well with good correction by the end of ten weeks. He reported these two cases in 1833.[28] Five years later he published a textbook on operative orthopedics that advocated the use of subcutaneous tenotomy for the corrections of all deformities caused by muscular contractures.[29]

Later on in his career, Stromeyer held professorial chairs at the universities of Erlangen, Freiburg, and Kiel. He also acquired a great deal of experience in military surgery, serving as the medical consultant to the Prussian army during the Franco-German War of 1870–71. He was considered by his contemporaries as the Larrey of his generation. Stromeyer's contribution to tenotomy was a product of his youth and his work in the orthopedic clinic in Hanover. To resurrect an old operation condemned by surgical authorities in Paris was a bold step for a young man. In view of the absence of anesthesia and antiseptic technique, some credit must also go to the bold patients who agreed to the operation.

William John Little (1810–1894) (figure 2.18) studied medicine in London. In spite of an equinus deformity of his left leg due to an attack of poliomyelitis at age four that necessitated the use of a brace, he completed his studies and became a member of the Royal College of Surgeons in 1832. He was determined to seek a correction of his deformity. Aware of the work of both Delpech and Stromeyer, he went to Germany in 1836 to obtain consultation regarding his case, visiting among other specialists Johann Friedrich Dieffenbach (1792–1847), the leading surgeon

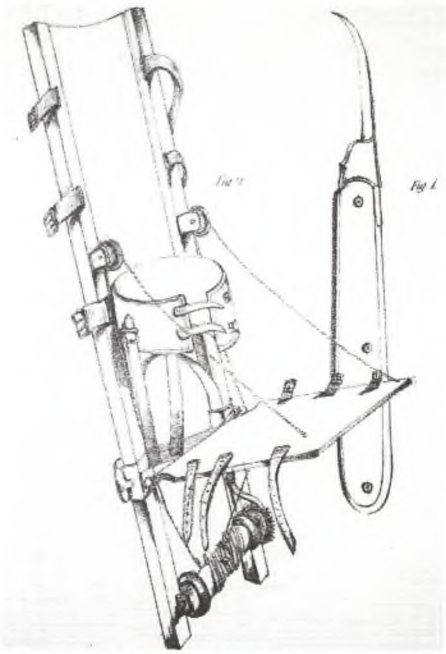


Figure 2.19 Dieffenbach's *tenotome* and corrective splint. From J. F. Dieffenbach, *Ueber die Durchschneidung der Sehnen und Muskeln* (Berlin: A. Förstner, 1841), pl. 3.

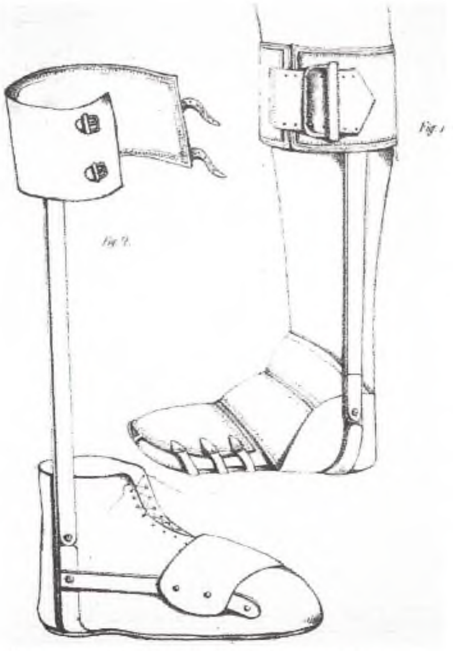


Figure 2.20 Dieffenbach's retention splint used to maintain correction. From Dieffenbach, *Durchschneidung der Sehnen und Muskeln*, pl. 4.

in Berlin. All of his consultants advised against the operation. However, his visit to Stromeyer's clinic, where he observed the operation and the results obtained, convinced him to allow Stromeyer to treat him in this fashion. The operation was a success and during his convalescence he learned how to do the procedure and manage the postoperative care.

Before returning to England, Little visited Dieffenbach again in Berlin. Very much impressed by the result Stromeyer had obtained, Dieffenbach took up the operation himself and within the next year had performed either subcutaneous tenotomy or myotomy in 140 patients.[30] It was not long after this that Dieffenbach published a book on subcutaneous tenotomy and myotomy based on an experience of over 1000 cases[31] (figures 2.19 – 2. 20).

Back in England, Little performed the first subcutaneous tenotomy in London on 20 February 1837. As a result of his experience with a large number of patients over the next two years, he was able to publish a monograph, *A Treatise on the Nature of Club-Foot*, in 1839.[32] In 1840 Little founded the first hospital in Britain devoted entirely to the treatment of orthopedic problems. This hospital, through the process of growth and amalgamation, evolved into what is now the Royal National Orthopaedic Hospital. Little had two sons who became surgeons; one, Louis Stromeyer Little was named for his teacher and benefactor; the other, Ernest Muirhead Little, became the first president of the British Orthopaedic Association. On the basis of his work, Little can be considered to be the founder of the specialty of orthopedics in Britain.[33]

Another student of Stromeyer's was William Ludwig Detmold (1808–1894) (figure 2.21), a native of Hanover, where his father was the court physician to the king. After obtaining his medical degree at the University of Göttingen in 1830, Detmold served as a surgeon in the Royal Hanovarian Guards. In the spring of 1837 he emigrated to the United States and began practice in New York City. In September of that year he carried out his first subcutaneous tenotomy and the following year published his first report, which gives a good description of his technique.[34] Two years later he was able to report on a group of 167 patients who underwent this procedure.[35]

In 1841 Detmold established a public clinic for the treatment of crippled children, the first such clinic in New York City. The clinic was at the College of Physicians and Surgeons and was continued until 1861, when his activity as a military surgeon in the Civil War took Detmold away from New York. In 1842 at the College of Physicians and Surgeons, he gave the first series of lectures on orthopedics to be presented in the United States. Detmold was a vigorous man who was very active in civic and medical affairs. A. R. Shands considered him to be the first American orthopedic surgeon.[36]

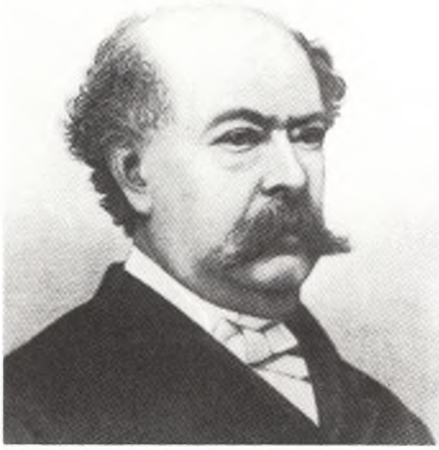


Figure 2.21 William Ludwig Detmold (1808–1894). Courtesy of the New York Academy of Medicine Library.

Figure 2.22 Jules Guérin (1801–1886). Courtesy of the New York Academy of Medicine Library.

In 1838 John Ball Brown (1784–1862) founded the Boston Orthopedic Institution. He had graduated from Harvard Medical School in 1813 and carried on a practice in Boston. His interest in orthopedics was stimulated by the the death of one son from poliomyelitis and the crippling of another by the disease. He began using tenotomy in 1839. Another son, Buckminster Brown (1819–1891), followed in his footsteps and was the first surgeon in the United States to limit his practice entirely to orthopedics. Although the Boston Orthopedic Institution closed in 1851, Buckminster Brown opened an orthopedic ward at the House of the Good Samaritan in Boston in 1861. He also established a chair of orthopedic surgery: the John Ball and Buckminster Brown Professorship in Orthopaedic Surgery at Harvard.[37]

Once the success of the operation was established, the practice of subcutaneous tenotomy for the treatment of deformities of the foot spread rapidly. In 1839 Raoul Henri Joseph Scoutteten (1799–1871), the professor of military surgery in Strasbourg, published his book on the radical cure of clubfeet by means of subcutaneous tenotomy.[38] In Paris the operation was brought to prominence by Jules Guérin (1801–1886) (figure 2.22). Guérin was born in French-occupied Belgium and educated at Louvain. He then obtained his medical degree in Paris in 1827. The next year he became the editor of the *Gazette de santé*. Established in 1773, this was the oldest medical journal in France. Under his leadership the journal flourished, becoming the *Gazette médicale de Paris* in 1830. By 1843 the journal, published weekly, had a circulation of fifteen hundred copies.[39]

Guérin became interested in the treatment of patients with skeletal deformities and in 1834 established an orthopedic institute to care for them. The Château de la Muette was in the Paris suburb of Passy, near the former residence of Benjamin Franklin. It was here that Guérin did most of his initial work. When the Paris Academy of Medicine proposed a question on *orthopédie* for the Monthyon Prize, the award was shared by Sauveur-Henri-Victor Bouvier and Guérin in 1837.[40] Guérin's entry consisted of sixteen folio volumes and five hundred drawings prepared over a period of seven years. Valentine Mott, the well-known New York surgeon, visited this hospital in 1834 and described one of Guérin's operations.

> *In one operation, some half a hundred nearly (In the case I refer to, forty three muscles and tendons were divided) of these ropes of the human body were cut asunder, and the patient stretched out upon the table in his natural shape.*[41]

In 1839 the governing body of the hospital system in Paris created an orthopedic service at the Hôpital des Enfans Malades and appointed Guérin as its chief without the usual competitive examination. This, as well as the claims he made in his published

Figure 2.24 A patient with torticollis before and after treatment by subcutaneous myotomy of the sternocleidomastoid muscle. From A. Bonnet, *Traité des sections tendoneuses et musculaires* (Lyon: Charles Savy Jeune, 1841), pl. 14.

Figure 2.23 Amédée Bonnet (1802–1858) From B. Valentin, *Geschichte der Orthopädie* (Stuttgart: Georg Thieme, 1961), 207.

papers, led to conflicts with his colleagues and culminated in a famous trial for libel that established the precedent for the free criticism of scientific papers.[42]

In Lyon, the development of the new specialty was in the hands of Amédée B. Bonnet (1802–1858) (figure 2.23). Bonnet studied in Paris in the early part of the eighteenth century, when it was the center of the medical world.[43] Receiving his medical degree in 1832, he went immediately to Lyon, where he became associated with the Hôtel Dieu. His practice flourished and he eventually was made the chief surgeon of the hospital and professor of surgery in the medical school. While he wrote on many surgical subjects, it is his work on joint diseases that remains most important. He believed in treating his patients by operative methods as well as by nonoperative means such as manipulation, splinting, and immobilization. His book, *Traité des sections tendoneuses et musculaires*, which appeared in 1841, discusses the use of subcutaneous tenotomy in the treatment of strabismus, myopia, stammering, clubfoot, deformities of the knee, torticollis, fractures, and other conditions[44] (figure 2.24).

Public interest in medical innovations was as keen then as as it is now. This was reflected in the literature of the time. In the novel *Madame Bovary* by Gustave Flaubert, an Achilles tenotomy served as one of the pivotal episodes. Flaubert's knowledge of surgery was greater than most writers because his father and brother were both distinguished surgeons. Flaubert chose to have a simple country doctor, Emma Bovary's husband Charles, perform the operation on Hippolyte, the stable boy at the Lion d'Or: "Charles pierced the skin; there was a sharp snap; the tendon was cut, the operation was over. Hippolyte was overcome with surprise. He bent over Bovary's hands and covered them

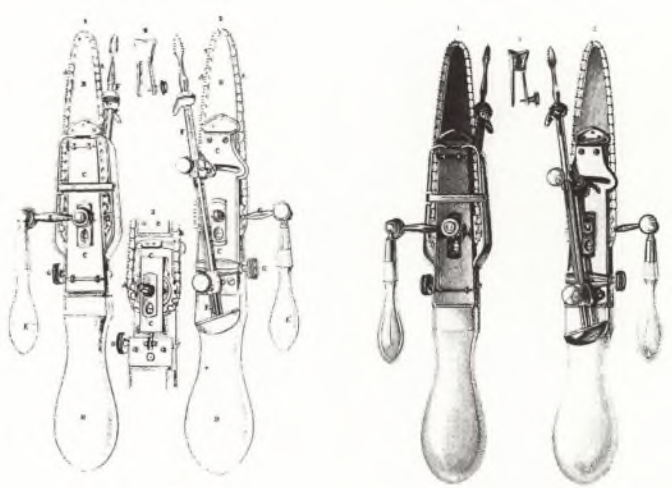


Figure 2.26 Bernhard Heine's *osteotome*, the first chain saw. From Joseph Greb, *Handbuch der allgemeinen und speciellen Chirurgie* (Erlangen: Ferdinand Enke, 1869), atlas 2, pl. 9.

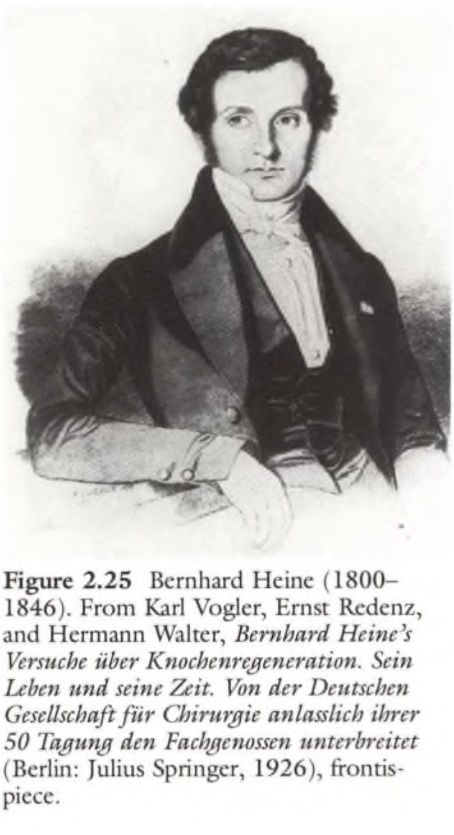


Figure 2.25 Bernhard Heine (1800–1846). From Karl Vogler, Ernst Redenz, and Hermann Walter, *Bernhard Heine's Versuche über Knochenregeneration. Sein Leben und seine Zeit. Von der Deutschen Gesellschaft für Chirurgie anlasslich ihrer 50 Tagung den Fachgenossen unterbreitet* (Berlin: Julius Springer, 1926), frontispiece.

with kisses."[45] During the postoperative period, while the foot was confined in an apparatus to obtain correction, pressure and ischemia led to the development of gangrene and eventually to the loss of the limb. For Madame Bovary, it was only one of many of her husband's failures.

The development of tenotomy and myotomy permitted the correction of many deformities, but there remained a large number of bony deformities that could not be corrected by these methods. While John Rhea Barton (1794–1871) of Philadelphia had divided the upper end of the femur with a special narrow saw in 1827, such methods did not provide for the protection of the adjacent soft tissue and were excessively painful.[46] The appearance of the first chain saw, designed by Bernard Heine (1800–1846) (figure 2.25), eliminated some of these problems. Heine was a member of a distinguished orthopedic family.[47] His uncle, Johann Georg Heine (1770–1838), began as an instrument and brace maker in Würzburg, and later became a member of the faculty of the University of Würzburg. In 1816 he founded an orthopedic institute in Würzburg that enjoyed the patronage of Queen Caroline of Bavaria. His uncle Jacob Heine (1799–1879) was the orthopedist who described the residual deformities following acute poliomyelitis; postpoliomyelitis paralysis is known as Heine-Medin's (for Oskar Medin; see chapter 6) disease for this reason.[48] At the age of ten, Bernhard began to work in his uncle's machine shop where he showed excellent mechanical aptitude. After graduating from the University of Würzburg he specialized in orthopedics. He devised many instruments, the most famous of which was his chain saw, also known as both a *Knochenbisturis* and an *osteotome* (figure 2.26). This instrument could be introduced through a small incision and had special appendages to protect the soft tissue. Heine started working on this idea in 1824 and perfected the instrument in 1830; it made him famous. After presenting his work in Paris, he was awarded a Monthyon Prize in 1835. In 1837 he spent six months in Russia demonstrating his technique, where he was a guest of the Czar. He was made professor of physiology and orthopedics at the University of Würzburg in 1838.

Using his chain saw, Heine conducted a large number of experiments on dogs, studying bone regeneration and fracture healing.[49] For this work he was awarded a second Monthyon Prize in 1838. Many of his observations and conclusions foreshadow the later work of Louis Xavier Ollier (1830–1900) and William Macewan (1848–1924). Unfortunately he did not live to see the fruits of his labor. He died of tuberculosis in 1846.

In the one hundred years between the appearance of Andry's book and that of Bonnet's, a whole new area of surgical specialization was established. A particular group of patients with deformities and disabilities, or as Bouvier was later to characterize them, "les maladies chroniques de l'appareil locomoteur," had been defined, and special hospitals, institutes, and services had been established for the care and treatment of these patients. Regimens of treatment with various physical modalities and types of apparatus were well developed. Most importantly, relatively safe and painless elective operative procedures had been introduced that had wide application in the treatment of these deformities. The new specialty of orthopedics was well positioned to take advantage of the discovery of anesthesia (1846) and the development of antiseptic technique (1865), and thus was able to rapidly expand its therapeutic armamentarium and activities during the next century.

Notes

1. Nicolas Andry, *L'Orthopédie, ou l'art de prévenir et de corriger dans les enfans, les difformités du corps* (Paris: la veuve Alix, 1741).

2. Scaevole de Sainte-Marthe, *Paedotrophiae, or, The Art of Nursing and Rearing Children*, trans. H. W. Tyler (London: John Nichols, 1797); G. Kasten Tallmadge, "Scaevola de Sainte-Marthe and the Paedotrophia," *Bull Hist Med* 7(1939): 279–314; Claude Quillet, *Callipaedia, or the Art of Getting Beautiful Children*, 3d ed., trans. N. Rowe (London: W. Feales, 1733); Ch. Guillemain, "Claude Quillet (1607–1661): Médicin, poète et abbé au XVIII siècle, sa *Callipedia*, ou l'art d'avoir de beaux enfants," *Cahiers Lyon hist méd* 4(1959): 3–23.

3. Andry, *Orthopaedia: or the Art of Correcting and Preventing Deformities in Children* (London: A. Millar, 1743).

4. Andry, *Orthopaedia*, 1:210–11.

5. Felix Wurtz, *Ein schoenes und nutzliches Kinderbuchlein* (Basel: S. Henricpetri, 1616).

6. John Ruhräh, *Pediatrics of the Past* (New York: Paul B. Hoeber, Inc., 1925), 215.

7. *Bartlett's Familiar Quotations*, 15th ed. (Boston: Little Brown & Co., 1980), 335.

8. H. Winnett Orr, "Nicolas Andry, Founder of the Orthopaedic Specialty," *Clin Orthop* 4(1954): 3–9.

9. P. Mauclaire, "Les Portraits de Nicolas Andry, le père et le parrain de l'orthopédie infantile," *Bull soc France hist méd* 32(1938): 209–14.

10. Andry, *Orthopaedia*, 1:36–37.

11. Ibid., 2:212–13.

12. G. Mercuriali, *De arte gymnasticae: libri sex; Artis gymnasticae apud antiquous celeberrimae, nostris temporibus ignoratae*; (Venice: Iuntas, 1569); L. F. Peltier, "Girolamo Mercuriali (1530–1606) and the First Illustrated Book on Sports Medicine," *Clin Orthop* 198(1985): 21–24.

13. Gerhard Grosch, "Jean-André Venel (1740–1791) und die Begründung der klassichen Orthopädie," *Gesnerus* 32(1975): 192–99.

14. Bruno Valentin, "Jean-André Venel, der Vater der Orthopädie," *Sudhoff's Archiv* 40(1956): 305–36.

15. William Coxe, *Travels in Switzerland*, 4th ed. (London: T. Cadell, 1789), 2:93–94.

16. Valentin, "Jean-André Venel," 305–36.

17. Roger T. Austen, *Robert Chessher of Hinckley, 1750–1831: First English Orthopaedist* (Leicestershire County Council Libraries & Information Service, 1981); Obituary: "Robert Chessher," *Med Surg J* (1831): 374–75.

18. J. M. Delpech, *Mémoire sur la complication des plaies et des ulcères connue sous le nom de pourriture d'hôpital* (Paris: Méquignonet Marvis, 1815).

19. O. H. Wangensteen and S. D. Wangensteen, *The Rise of Surgery from Empiric Craft to Scientific Discipline* (Minneapolis: University of Minnesota Press, 1978), 6.

20. Delpech, *De l'Orthomorphie par rapport à l'espèce humaine* (Paris: Gabon, 1828).

21. Delpech, *Chirurgie clinique de Montpellier; ou, observations et réflexions tirées des travaux de chirurgie clinique de cette école* (Paris et Montpellier: Gabon et Cie, 1823), 1:147–231.

22. John Hunter had described a spontaneous rupture of his own Achilles tendon that occurred while he was dancing. Hunter treated himself by wearing a shoe with a high heel and constricting the calf muscle with a bandage to limit its contractility. Subsequent to his recovery he carried out several experiments on dogs, dividing the Achilles tendon with a small knife in the manner of subcutaneous tenotomy, and sacrificing them at intervals to study the process of healing. Drewry Ottley, "The Life of John Hunter, F.R.S.," in *The Works of John Hunter, F.R.S.*, ed. James F. Palmer (London: Longman, Rees, Orme, Brown, Green and Longmans, 1835), 1:33–34.

23. Delpech, *Chirurgie clinique de Montpellier*, 1:321–57.

24. Ibid., 1:231.

25.Delpech, *De l'Orthomorphie*, 2:358–59.

26. G. Dupuytren, *Leçons orales de clinique chirurgicale*, 2d ed. (Paris: Germer-Baillière, 1839), 3:455–61.

27. C. Averill, *Short Treatise on Operative Surgery* (London, 1823), 61–64.

28. L. Stromeyer, "Die Durchschneidung der Achillessehne, als Heilmethode des Klumpfüsses, durch zwei Fälle erlautert," *Mag ges Heilk* 39(1833): 195–218.

29. Stromeyer, *Beiträge zur operativen Orthopädik* (Hanover: Helwing, 1838).

30. R. M. Goldwyn, "Johann Friedrich Dieffenbach (1794–1847)," *Plas Recon Surg* 42(1968): 19–28.

31. J. F. Dieffenbach, *Ueber die Durchschneidung der Sehnen und Muskeln* (Berlin: A. Förstner, 1841).

32. W. J. Little, *A Treatise on the Nature of Club-Foot and Analogous Distortions; Including Their Treatment Both with and without Surgical Operation.* (London: Longman, Brown, Green, and Longmans, 1839).

33. A. R. Jones, "William John Little," *J Bone Joint Surg* 31B(1949): 123–26.

34. W. L. Detmold, "Reports of Several Cases of Successful Operations for Clubfoot by Division of the tendo Achilles, with Remarks," *Am J Med Sci* 22(1838): 105–16.

35. Detmold, "An Essay on Clubfoot and Some Analogous Diseases,", *NY Quart J Med Surg* 2(1840): 1–64.

36. A. R. Shands, Jr., *The Early Orthopaedic Surgeons of America* (St. Louis: C.V. Mosby Co., 1970), 14.

37. J. Cohen, "The Boston Orthopedic Institution," *J Bone Joint Surg* 40A(1958): 1176–78.

38. H. Scoutteten, *Ueber radicale Heilung der Klumpfüsse*, trans. W. Walther (Leipzig: Leopold Michelsen, 1839).

39. F. C. Stewart, *The Hospitals and Surgeons of Paris* (New York: J. & H. Langley, 1843), 295–300.

40. Established by a bequest from the philanthropist Antoine Jean Monthyon (1733–1820).

41. Valentine Mott, *Travels in Europe and the East* (New York: Harper & Brothers, 1842), 55.

42. Peltier, "Guérin versus Malgaigne: A Precedent for the Free Criticism of Scientific Papers," *J Orthop Res* 1(1983): 115–18.

43. Maurice Patel, "Amédée Bonnet (1809–1858)," *Progrès méd* 83(1955): 287–90.

44. Bonnet, *Traité des sections tendoneuses et musculaires* (Lyon: Charles Savy Jeune, 1841).

45. Gustave Flaubert, *Madame Bovary*, trans. Lowell Bair (Toronto: Bantam Books, 1981), 152.

46. John Rhea Barton, "On the Treatment of Anchylosis by the Formation of Artificial Joints," *N Am Med Surg J* 3(1927): 279–92.

47. Karl Vogler, *Bernhard Heine's Versuche über Knochen regeneration. Sein Leben und seine Zeit. Von der Deutschen Gesellschaft für Chirurgie anlasslich ihrer 50 Tagung den Fachgenossen unterbreitet* (Berlin: J. Springer, 1926), 1–54.

48. Jacob Heine, *Beobachtungen über Lahmungszustande der untern Extremitäten und deren Behandlung* (Stuttgart: Kohler, 1840).

49. Ernst Redenz and Hermann Walter, *Bernhard Heine's Versuch über Knochenregeneration. Sein Leben und seine Zeit. Von der Deutschen Gesellschaft für Chirurgie anlasslich ihrer 50 Tagung den Fachgenossen unterbreitet.* (Berlin: J. Springer, 1926), 55–203.

CHAPTER THREE

Congenital Deformities

THE SURVIVAL OF A PATIENT with a congenital deformity depends upon two factors: the nature of the deformity and the support for the handicapped individual that can be provided by his family or social group. Some deformities are so life-threatening as to be incompatible with survival under any circumstances. Others permit the patient to grow and be absorbed completely into the life and culture of his community. Most conditions fall somewhere in between these two poles. The two most frequent congenital deformities whose diagnosis and treatment contributed to the development of the specialty of orthopedic surgery were clubfeet and dislocation of the hip. The congenital clubfoot deformity is present and obvious at birth. It is an immediate and continuing cause of disability. The congenital dislocaton of the hip, on the other hand, is not obvious at birth, and indeed the patient may go several years or longer before a deformity or disability becomes evident.

The treatment, etiology, and even pathological anatomy of congenital idiopathic clubfoot unfortunately are still controversial. A universally accepted method of classification of the severity of the deformity is lacking, and no standardized method of evaluating the results of treatment has been developed yet.[1]

This statement opened a review article on the operative treatment of congenital clubfeet, which was published in 1988. It points out the fact that in spite of years of observation and investigation, there are large gaps in our knowledge of the etiology and pathological anatomy of clubfeet and that our treatment of this condition is largely empirical. Clubfoot, *piedbot*, and *klumpfuss* are descriptive terms from the vocabulary of the layman. The medical

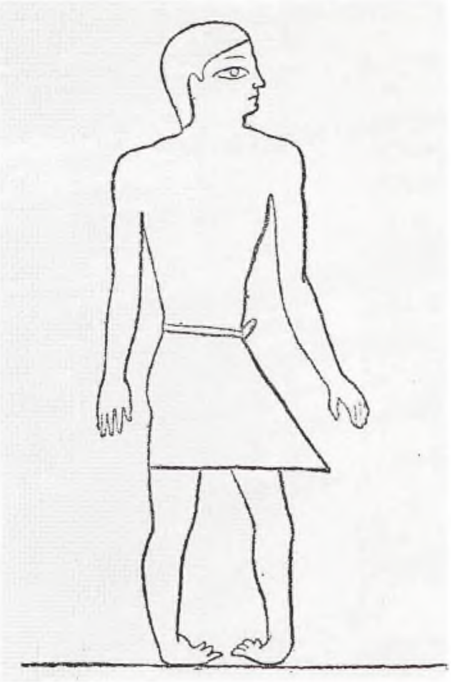
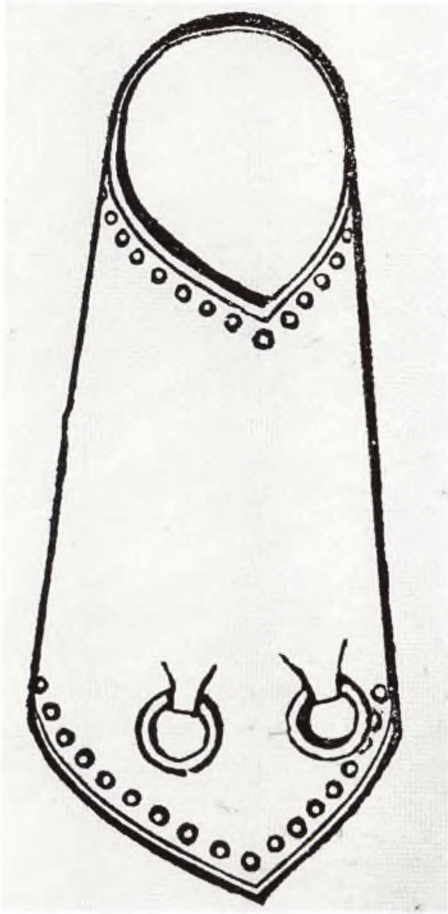


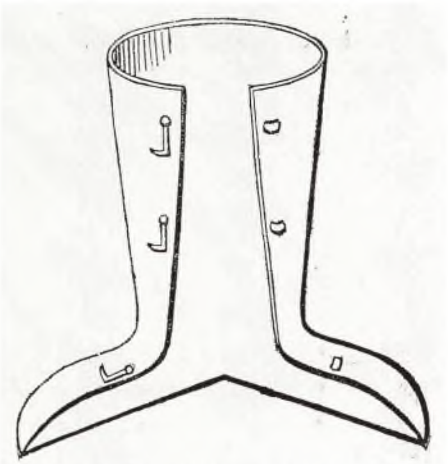
Figure 3.1 A drawing of an adult male with bilateral clubfeet from the wall of an Egyptian tomb. From J. M. Charcot and Paul Richer, *Les difformes et les malades dans l'art* (Paris: Lecrosnier et Babe, 1889), 64.

terms are descriptive also, though without a hint of the etiology. The generic term, *Talipes*, is derived from the Latin words *talus* (astragalus) and *pes* (foot), and literally means to walk on the ankles. The species, which may be equinus, calcaneous, valgus, or varus, indicates only the direction the foot is turned by the deformity. These deformities can occur singly or in association with a variety of conditions, including myelomeningocele, arthrogryposis, cerebral palsy, and poliomyelitis.

A drawing from an Egyptian temple indicates that the deformity known as clubfoot has been recognized for centuries and that it was possible to reach adulthood without correction of the deformity (figure 3.1). Nevertheless, it would be a mistake to believe that attempts were not made from the earliest of times to place the feet in a plantigrade position. The method used by Hippocrates was based on a long tradition.

Wherefore, then, some of these congenital displacements, if to a small extent, may be reduced to their natural condition, and especially those at the ankle-joint. Most cases of congenital club-foot are remediable, unless the declination be very great, or when the affection occurs at an advanced period of youth [poliomyelitis?]. *The best plan, then, is to treat such cases at as early a period as possible, before the deficiency of the bones of the foot is very great, and before there is any great wasting of the flesh of the leg. There is more than one variety of club-foot, the most of them being not complete dislocations, but impairments connected with the habitual maintenance of the limb in a certain position. In conducting the treatment, attention must be paid to the following points: to push back and rectify the bone of the leg at the ankle from without inward, and to make counter-pressure on the bone of the heel in an outward direction, so as to bring it into line, in order that the displaced bones may meet at the middle and side of the foot; and the mass of the toes, with the great toe, are to be inclined inward, and retained so; and the parts are to be secured, with cerate containing a full proportion of resin, with compresses, and soft bandages in sufficient quantity, but not applied too tight; and the turns of the bandages should be in the same direction as the rectifying of the foot with the hand, so that the foot may appear to incline a little outward. And a sole made of leather not very hard, or of lead, is to be bound on, and it is not to be applied to the skin but when you are about to make the last turns of the bandages. And when it is all bandaged, you must attach the end of one of the bandages that are used to the bandages applied to the inferior part of the foot on the line of the little toe; and then this bandage is to be rolled upward in what is considered to be a sufficient degree, to above the calf of the leg, so that it may remain firm when thus arranged. In a word, as if moulding a wax model, you must bring to their natural position the parts which were abnormally displaced and contracted together, so rectifying them with your*





Figures 3.2–3.3 Devices used by Ambroise Paré: 3.2: Slipper with rings for ribbons to hold the foot in dorsiflexion; 3.3: A metal boot to maintain correction. From *Oeuvres complètes d'Ambroise Paré*, trans. J.-F. Malgaigne (Paris: J. B. Baillière, 1840), 613, 615.

hands, and with the bandaging in a like manner, as to bring them into their position, not by force, but gently; and the bandages are to be stitched so as to suit the position in which the limb is to be placed, for different modes of the deformity require different positions. And a small shoe made of lead is to be bound on externally to the bandaging, having the same shape as the Chian slippers had. But there is no necessity for it if the parts be properly adjusted with the hands, properly secured with the bandages, and properly disposed of afterward. This, then, is the mode of cure, and it neither requires cutting, burning, nor any other complex means, for such cases yield sooner to treatment than one would believe. However, they are to be fairly mastered only by time, and not until the body has grown up in the natural shape; when recourse is had to a shoe, the most suitable are the buskins [a boot], *which derive their name from being used in traveling through mud, for this sort of shoe does not yield to the foot, but the foot yields to it. A shoe shaped like the Cretan is also suitable.*[2]

The original Hippocratic text and the commentaries of Galen and other ancient authors on the treatment of clubfeet have been discussed throroughly by M. Michler.[3]

Almost two thousand years later, Ambroise Paré (1510–1590) described essentially the same technique for the treatment of varus and valgus forms of clubfeet. He also used some ingenious slippers and boots to help maintain the correction (figures 3.2 – 3.3). This tradition was based upon the following principles: (1) begin treatment early,[4] (2) slowly correct the deformity by repeated gentle manipulations, (3) maintain correction over a long period of time by the use of suitable bandages followed by corrective shoes.[5]

Nicolas Andry (1658–1747), in a section from his work *Orthopaedia*, which is aptly entitled "The Feet Deformed, By Having Taken a Wrong Turn," provided the following commentary:

If the Foot is not quite maimed, and past all possibility of forming it right, you may help it by the following Means. 1. By having recourse to those Remedies which soften the Ligaments, as Fomentations of Tripe-Broth, Frictions with the Oil of Lillies, and Poultices made with the Leaves and Roots of Marsh-mallows. 2. By trying with the Hand every day, to bring back the Foot to its natural Situation. 3. By employing for this purpose, strong Paste-board, Splints of Wood, or small Plates of Iron, which you must fasten carefully with a Bandage. These are better than all the Buskins which are usually employed upon these Occasions.[6]

As might be expected, many (if not the majority), of children with clubfeet who received any treatment at all were managed by irregular practitioners or bonesetters. William Cheselden (1688–1752) has given this account of their methods:

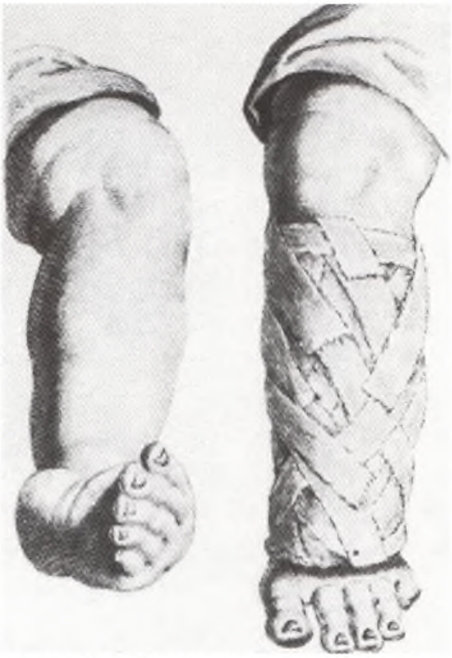


Figure 3.4 The bandage made from rags dipped into egg white and flour used by William Cheselden for the treatment of clubfeet. From Bruno Valentin, *Geschichte der Orthopädie* (Stuttgart: Georg Thieme, 1961), 75.

Children are sometimes born with their feet turned inwards, so that the bottom of the foot is upwards: in this case the bones of the tarsus, like the vertebrae of the back in crooked persons, are fashioned to the deformity. The first knowledge I had of a cure of this disease was from Mr. Presgrove, a professed bone-setter, then living in Westminster. I recommended the patient to him, not knowing how to cure him myself. His way was by holding the foot as near the natural posture as he could, and then rolling it up with straps of sticking plaster, which he repeated from time to time, as he saw occasion, until the limb was restored to a natural position, but not without some imperfection, the bandaging wasting the leg, and making the top of the foot swell and grow larger. After this, having another case of this kind under my care, I thought of a much better bandage, which I had learnt from Mr. Cowper, a bone-setter at Leicester, who set and cured a fracture of my own cubit when I was a boy at school. His way was, after putting the limb in a proper posture, to wrap it up in rags dipped in the whites of eggs, and a little flour mixed; this drying, grew stiff, and kept the limb in a good posture . . . When I used this method to the crooked foot, I wrapt up the limb almost to the knee to the toes, and caused the limb to be held in the best posture till the bandage grew stiff, and repeated the bandage once a fortnight[7] (figure 3.4).

Charles White (1728–1813) of Manchester used the method described by Cheselden with the addition of a leather-covered tin splint for added support and protection.8 The use of sticking plaster in the form of moleskin continued to be used for many years to bandage clubfeet and found its advocates in Julius Wolff (1836–1902) of *Wolff's Law* and Lewis A. Sayre (1820–1900) of New York.[9]

Another method of correction which enjoyed some popularity at the beginning of the nineteenth century was Bruckner's bandage (*fascia Bruckneri*), devised by Karl August Bruckner (1769–1797), a student of Jean André Venel (1740–1791), who died at twenty-eight of tuberculosis.[10] This bandage was particularly useful in very young children.

The following is the mode of applying Bruckner's bandage. Take about a square yard of flannel, and fold it in a triangular shape, the apex of which is to be folded over as often as is required, to give the whole cloth the shape of a roller, the middle of which is about the breadth of two fingers. One end of this bandage is to be applied obliquely from below the calf of the leg to the tendo Achillis, and it is to be given to an assistant to hold. The other end of this bandage is carried above the the outer ankle upon the upper part of the foot, over the inner ankle to the tendo Achillis, and again obliquely downwards over the upper part to the sole of the foot, and from it on the outer edge of the foot, keeping the bandage always tense, so that, by these two turns, the fore part of the foot is gradually turned and *drawn from within outwards. Having done this, take the two ends of the bandage, and cross them tightly over the outer edge of the foot, near to the outer ankle, making a knot similar to that used by merchants in packaging their bales of goods; and, lastly, finish by a turn round the ankle and a common knot.*[11]

This method had the disadvantage that the patient could not be allowed to walk. However, since it was used most commonly in infants, this did not seem to be a problem.

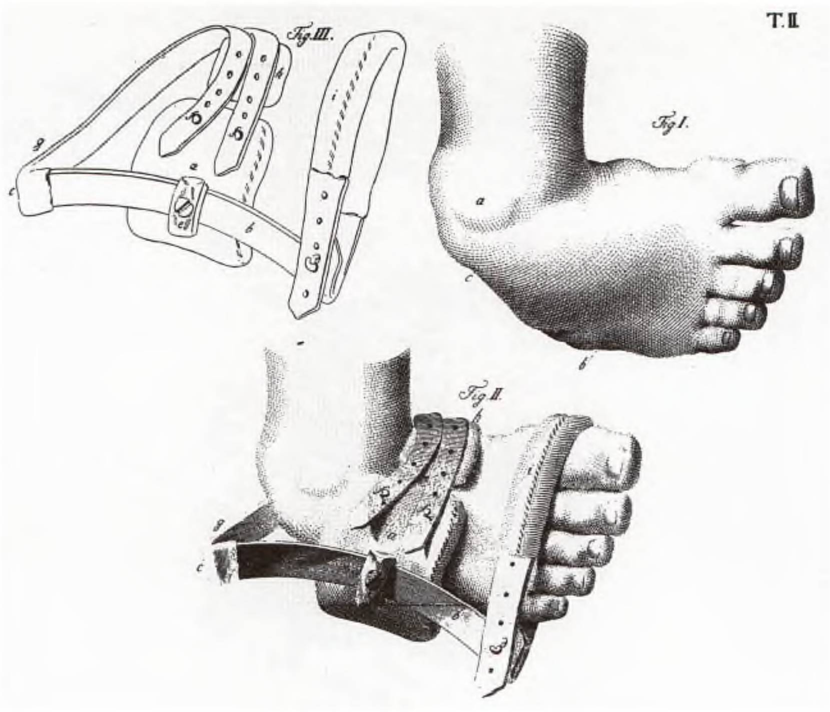
The first description of the pathological anatomy of clubfeet was given by Antonio S. Scarpa (1752–1832) (figure 3.5). Scarpa, a student of Giovanni Morgagni, was the professor of anatomy and theoretical surgery at Pavia. He traveled widely throughout Europe and was an accomplished linguist and artist. He made substantial contributions to the study of anatomy and surgery. In his book *Memoria chirurgica sui piedi torti congenita dei fanciulli e sulla maniera di correggere questa deformita*, published in Pavia in 1803, he described his methods of treatment, which relied on gentle manipulation and the use of braces incorporating steel springs[12] (figures 3.6 – 3.9). He believed that the patients should be ambulatory during the treatment. On the basis of his anatomical studies (figure 3.10), he observed that

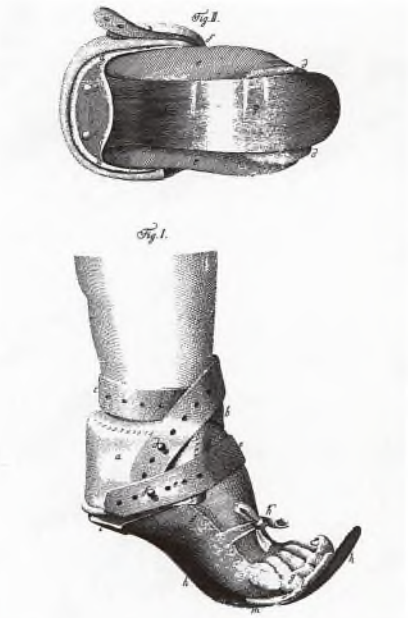
Figure 3.5 Antonio S. Scarpa (1747–1832). From C. E. Tobin and J. A. Benjamin, "Anatomical Study and Clinical Consideration of the Fascia Limiting Urinary Extravasation from the Penile Urethra," *SGO* 179(1944): 195.

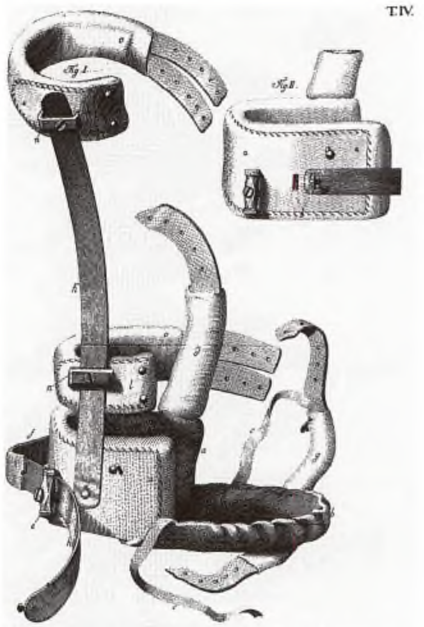
on dissecting the feet of such unfortunate children, we find that the bones of the tarsus are not, properly speaking, dislocated, but merely removed, in part, from their mutual contact, and twisted around their smaller axis. This displacement and twisting round the smaller axis, are more remarkable in the os naviculare, the cuboides, and os calcis, and much less in the astragalus, without, however, either of these bones quitting entirely the cavity, or acetabulum, in which they are contained.[13]

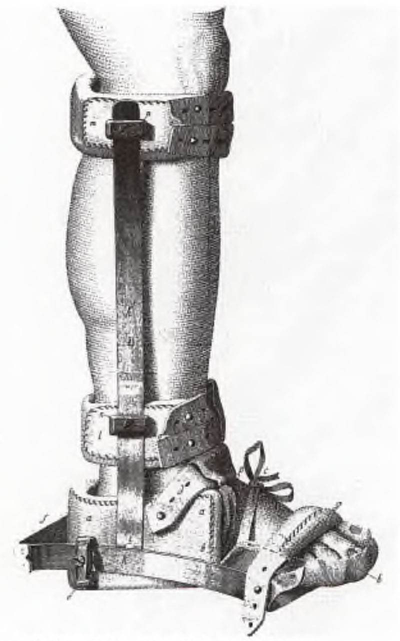
Sixty years later, William Adams (1820–1900) (figure 3.11), on the basis of the dissection of thirty clubfeet, concluded that the major bony deformity involved the astragalus.[14] The more recent work of Roshen N. Irani and Mary S. Sherman supported the opinion of Adams, namely, that the astragalus was always deformed.[15]

William Adams was born and lived in London all of his life.[16] He studied at the medical school of St. Thomas's Hospital. In 1842 he became curator and demonstrator of pathology for the hospital and served in this capacity for twelve years. During this period he had ample opportunity to pursue his anatomical investigations into tendon healing and to dissect specimens from patients of all ages who had clubfeet. He later became associated with the Royal Orthopaedic Hospital. Adams became the leading orthopedic surgeon of his time in England, succeeding his teacher, W. J. Little (1810–1894), in this role. In the treatment of clubfeet he emphasized that the forefoot deformity should be corrected first and then the foot brought up out of equinus utilizing a subcutaneous tenotomy of the Achilles tendon if necessary.









Figures 3.6–3.9 Plates showing Scarpa's braces for the treatment of clubfeet. They are typical of the era. From Scarpa, *Memoria chirurgica sui piedi torti congenita dei fanciulli e sulla maniera di correggere questa deformita*, 2d ed. (Pavia: Baldassare Comino, 1806), pls. 2–5.

Figure 3.10 One of Scarpa's anatomical dissections of a clubfoot. From Scarpa, *Memoria chirurgica sui piede torti congenita*, pl. 1.

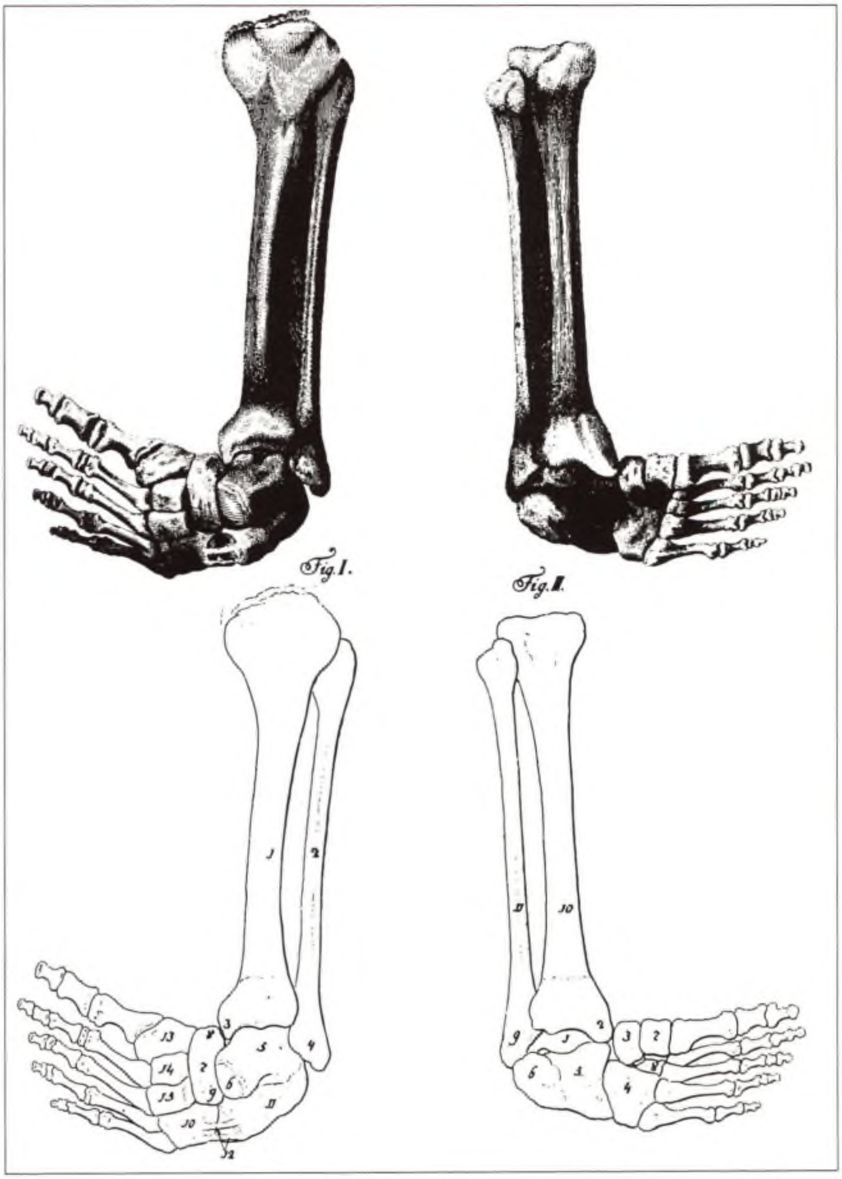


Figure 3.11 William Adams (1820–1900). From Arthur Rocyn Jones, "William Adams," *J Bone Joint Surg* 33B(1951): facing p. 124.

Figure 3.12 Father and three siblings with clubfeet. From G. Joachimsthal, *Handbuch der Orthopaedischen Chirurgie* (Jena: Gustav Fischer, 1905–1907), 2:596.

The cause of the clubfoot deformity still remains an enigma, although the popular view has held, without any evidence, that it is caused by intrauterine position. After a thorough investigation Max Bohm concluded that "the theory of a localized primary endogenous retardation of growth of the embryo best explains the majority of congenital club feet."[17] The genetics and inheritance of clubfeet have also remained obscure. In some families there is strong evidence of inheritance as a dominant trait (figure 3.12). Ruth Wynne-Davies, a great student of the inheritance of orthopedic disorders, concluded: "The deformity probably results from a genetic predisposition acting with some local intra-uterine factor. The exact nature of these is obscure."[18]

Jason Hiram Kite (b. 1891) (figure 3.13), after reviewing all of the literature on causation, drew no conclusions and offered the following quotation from Ecclesiastes 11.5: "As thou knowest not what is the way of the spirit, nor how the bones do grow in the womb of her that is with child: even so thou knowest not the works of God who maketh all."[19]

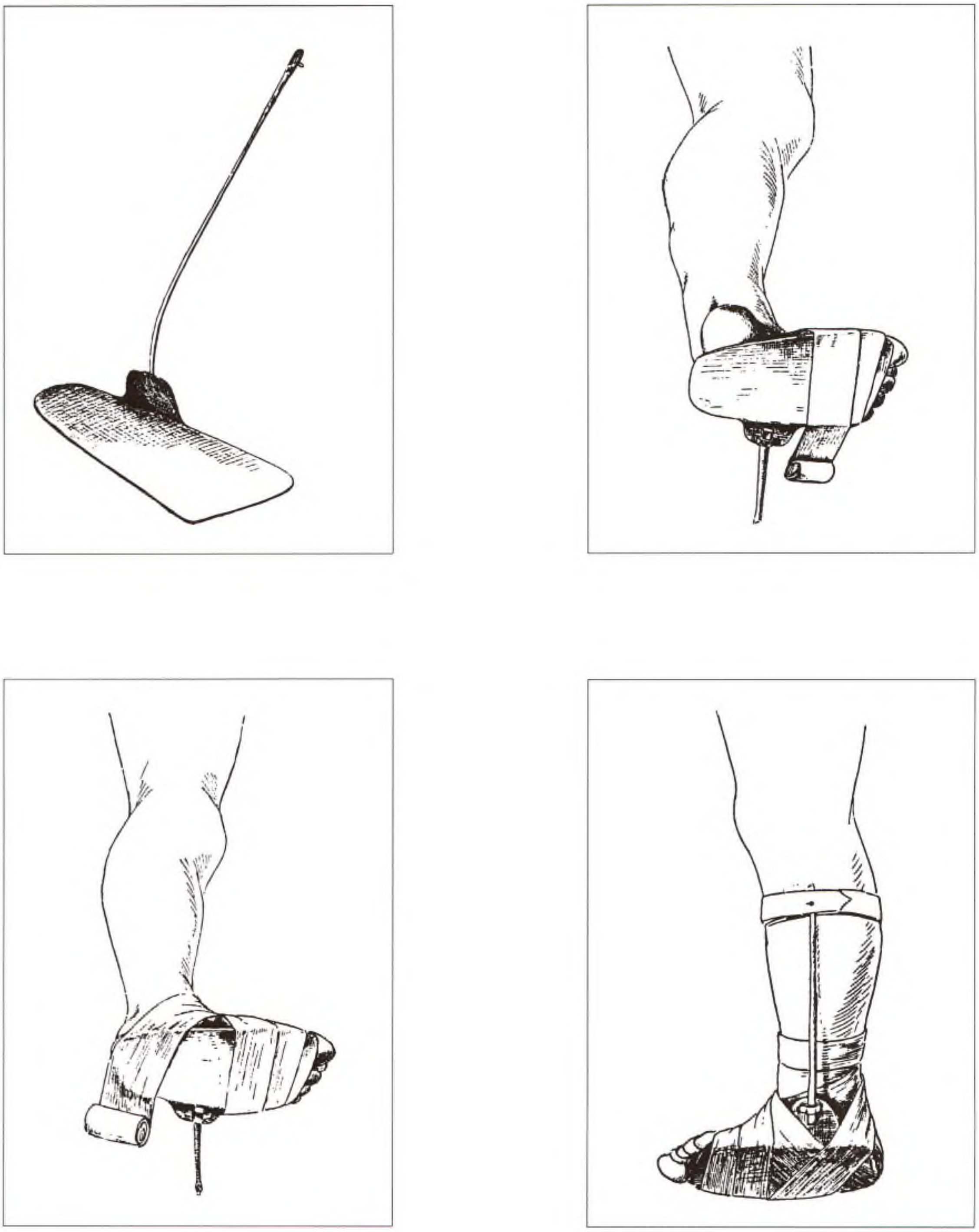
Kite was a Virginian and a graduate of Johns Hopkins Medical School where he had his postgraduate training. He established his practice in Atlanta, where he remained active for the next fifty years. In the position of surgeon-in-chief of the Scottish Rite

Figure 3.13 J. Hiram Kite (b. 1891). From *Clin Orthop* 84(1972): 7.

Hospital for Crippled Children in Decatur, Georgia (now a suburb of Atlanta), he served the crippled children of the area and accumulated a broad experience. Not only did he see fresh cases of clubfeet, he also saw the neglected and incompletely treated cases in the older children. He incorporated all of his experience in a book on clubfeet, which presents his generally conservative point of view and is valuable, in addition, for its thorough review of the literature on the subject.[20] Kite was known particularly for his techniques in the use of plaster of paris dressings in the management of the deformity.

The use of plaster of paris casts and bandages was introduced in the eighteenth century and filled a great need. Cheselden's mixture of flour and egg white left much to be desired as a method of bandaging club feet. H. Bouvier mentions that the starch bandages used for the treatment of fractures by Jean François Seutin (1795–1865) and Alfred Velpeau (1795–1867) were also applied to the treatment of clubfeet, but these were quickly outmoded.[21] The technique of using plaster of paris casts for the treatment of fractures used by Johann Friedrich Dieffenbach (1792–1847) in Berlin was also used by him in the treatment of clubfeet. Using this method, after oiling the skin, the leg was placed in a small box with removable sides. An assistant held the foot in the corrected position while a mixture of plaster of paris and water was poured around the limb in the box and allowed to set. After the plaster of paris had hardened, the box was removed and the foot and leg were, literally, contained in a cast. A notice of this method was published in the *Gazette médicale de Paris* on 23 April 1831 and Dieffenbach himself demonstrated the technique while on a trip to Paris in 1832.[22] Jules Guérin rapidly adopted it and his use of the technique was noted by *Lancet* in 1936: "We lately published an account of a new method proposed by M. Guérin, which consists in moulding a quantity of plaster of paris round the deformed limb, and thus applying mechanical uniform pressure to all points in its circumference."[23] Because of this notice, Guérin has frequently been given the credit for the development of this method. These plaster of paris casts were quickly discarded for the plaster of paris bandages developed by Antonius Mathijsen (1805–1878).[24] Because the material was inexpensive, readily available, and easy to use, bandages of plaster of paris were used throughout the world for the care of clubfeet at all stages of their treatment.

For those orthopedists who did not choose to use plaster of paris bandages in the early treatment of clubfeet, there were a variety of alternatives. Jean François Calot (1861–1944) employed a splint much like that of Venel[25] (figures 3.14 – 3.17). Some orthopedists used a system of strapping with adhesive plaster, a method which was attributed to Robert Jones[26] (figure 3.18).



Figures 3.14–3.17 The splint used by Calot for the treatment of clubfeet. This closely resembles the method used by Venel: Top left: the splint; Top right: the splint bandaged to the forefoot; Bottom left: the medial deviation of the foot corrected; Bottom right: the splint applied. The side piece of the splint was a spring that pulled the foot into eversion. From F. Calot, *Indispensable Orthopaedics*, trans. A. H. Robinson and Louis Nicole (London: Bailliere, Tindall & Cox, 1914), 825–27.

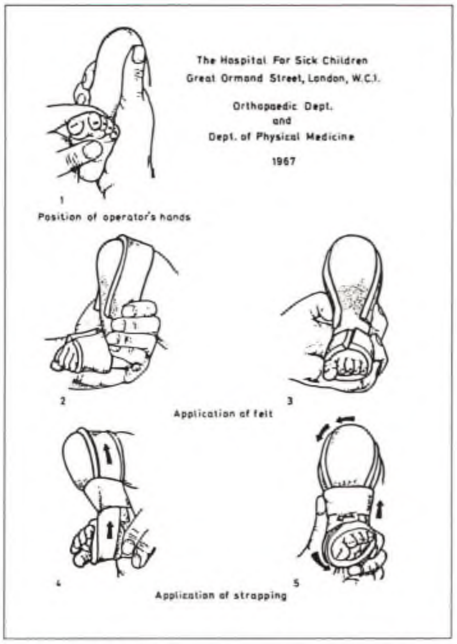


Figure 3.18 A method of strapping for the treatment of clubfeet attributed to Robert Jones. From G. G. Lloyd-Roberts, *Orthopaedics in Infancy and Childhood* (New York: Appleton-Century-Crofts, 1971), 288.

One of the most widely used types of splints employed in the early treatment of clubfeet was the Denis Browne splint. In this technique, both feet were attached to splints separately and then the splints connected with a bar (figure 3.19). The patient was allowed to kick and stretch the Achilles tendon and the one leg exercised the other.[27]

Denis Browne (1893–1967) (figure 3.20) was an Australian who graduated from the University of Sydney in 1914, just in time to join the army.[28] As a member of the Anzacs, he served in the Gallipoli campaign, and when mustered out after four years of service, he remained in London to pursue further training. He did not make a return visit to Australia until after he had retired. After obtaining his F.R.C.S. in 1922, he joined the staff of the Hospital for Sick Children, Great Ormond Street, where he remained active until 1957. Browne was one of the great pediatric surgeons of his generation and did much to establish pediatric surgery as a specialty in Britain. An unusually talented man with wide interests, he was independent in his thinking and something of an iconoclast.

The discovery of anesthesia in 1846 allowed surgeons to abandon gentle persuasion for more forceful methods. Thus began an era of *brissement forcé,* or forcible manipulation. A wide variety of equipment, simple and complicated, was used to bring the foot into compliance with the wishes of the surgeon. Admittedly, such methods were used particularly for cases in which gentle methods had failed or for cases of more advanced, rigid deformity, but they appear to have been almost the norm. Adolf Lorenz in Vienna was a great advocate of *modellirende Redressement* (a molding of the feet for correction) in the treatment of clubfoot and used a variety of devices to gain mechanical advantage, including a wedge-shaped block of wood[29] (figure 3.21). John Ridlon and Charles Eikenbary illustrated several methods of obtaining correction under anesthesia, including hand modeling over a wedge-shaped block of wood and application of the Thomas wrench[30] (figures 3.22 – 3.25). Virgil P. Gibney of New York presented a paper at a meeting of the American Orthopaedic Association in 1889 in which he advocated the use of the Thomas wrench in the treatment of clubfeet.[31] The paper was discussed by some of his colleagues, each of whom had a wrench of his own design. The equipment used by Abel Mix Phelps (1873–1902) seemed to embody the principle of Archimedes, that is, "Give me a lever long enough and I will move the world"[32] (figure 3.26). Such cumbersome and powerful instruments were not unusual. Following manipulation, the feet were placed in splints or wrapped with plaster of paris bandages. These methods were not without their immediate complications, however, as shown by the report by E. W. Ryerson of Chicago. This account tells of several deaths from fat embolism associated with crushing of the bones during

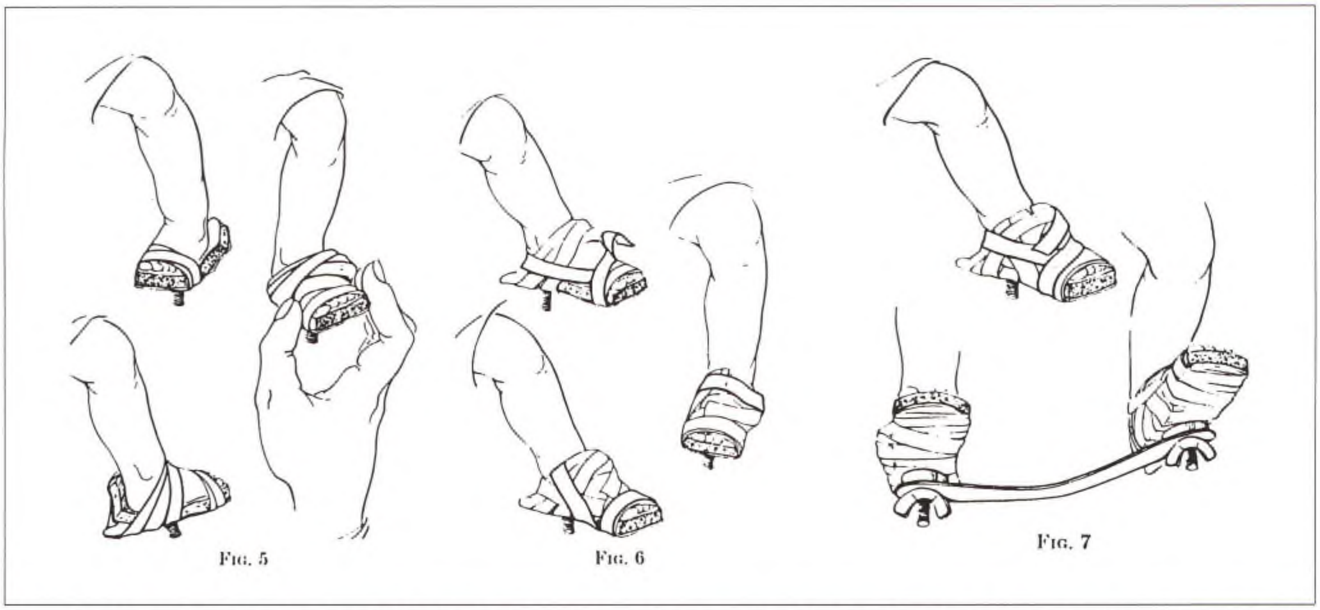


Figure 3.19 The Denis Browne splint: Fig. 5: the splint was first bound to the forefoot; Fig. 6: the forefoot adduction and inversion were then corrected; Fig. 7 the splints were then connected to a bar. All types of foot splints using a bar to connect the splints or shoes are derived from the Denis Browne splint. From S. A. Thomson, "Treatment of Congenital Talipes Equinovarus with a Modification of the Denis Browne Method and Splint," *J Bone Joint Surg* 24(1942): 291–98.

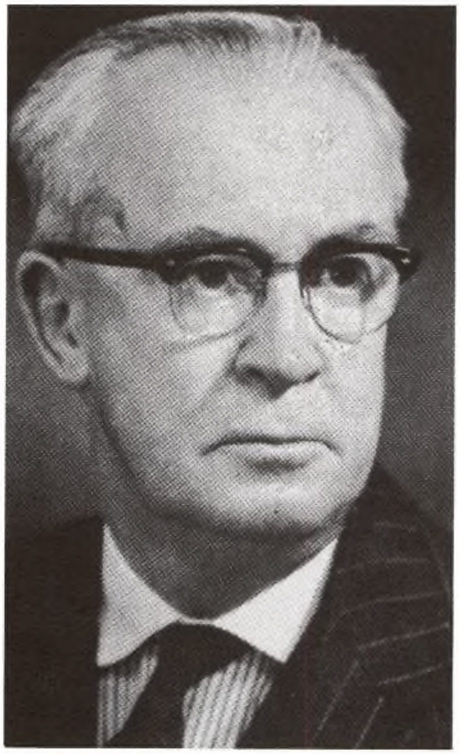


Figure 3.20 Denis John Wolko Browne (1893–1967). From *Brit Med J* 1(1967): 166.

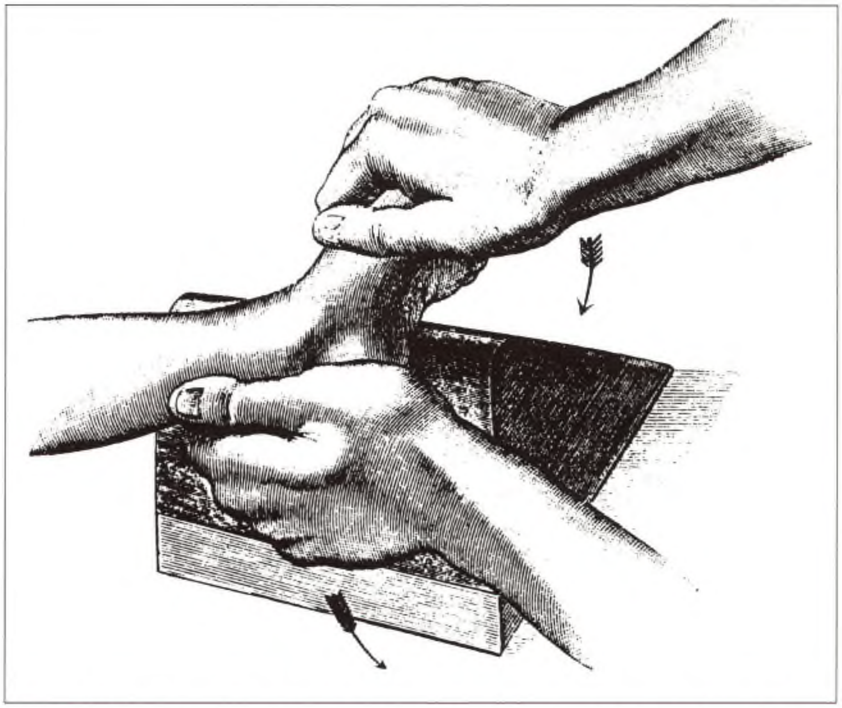
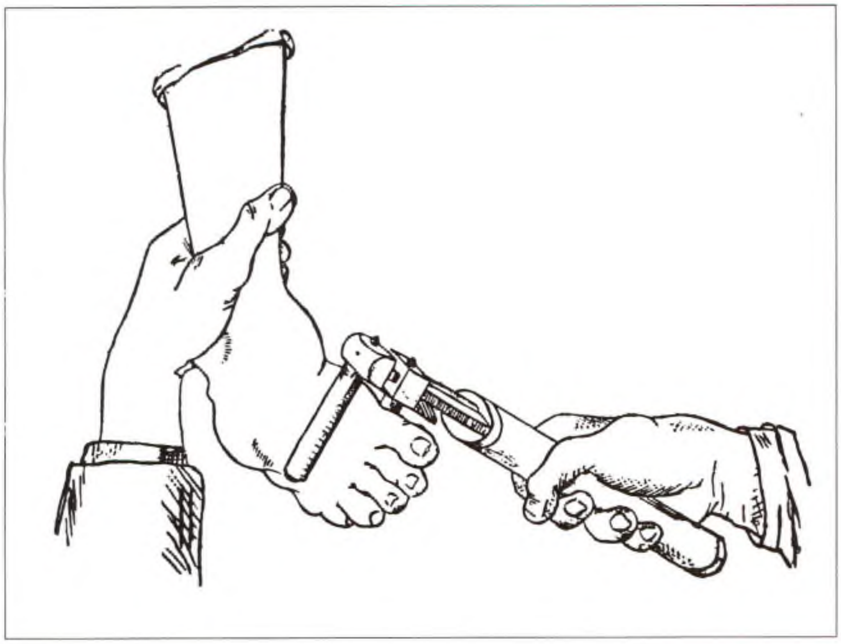


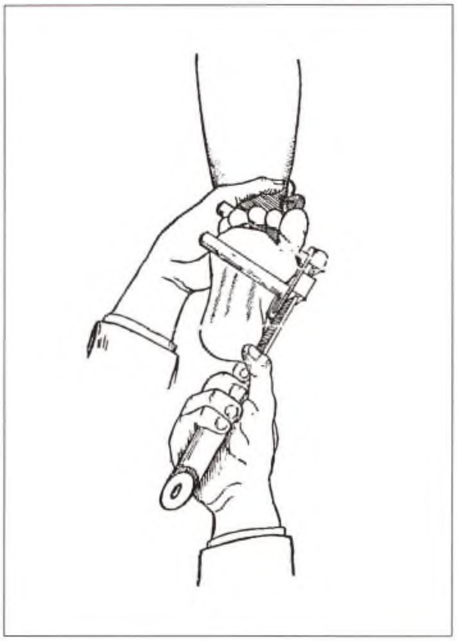
Figure 3.21 "Hand modeling" or *modellierende redressement*, the forceful manipulation of a clubfoot over a wooden wedge. From Adolf Lorenz, "Heilung des Klumpfuss dürch des modellierende Redressement," *Wien Klin* 21(1895): 299.

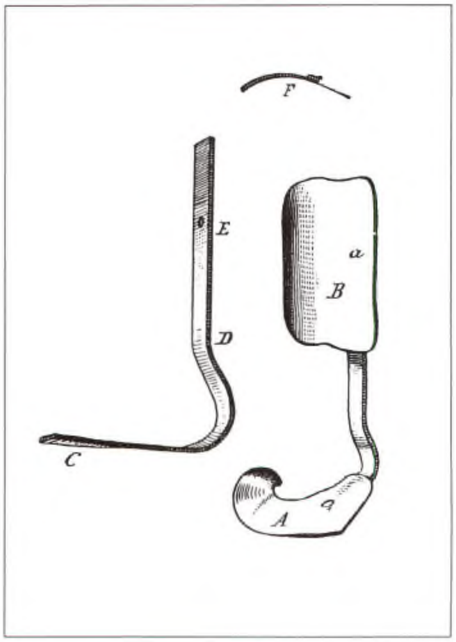
forcible manipulation of clubfeet.[33] The late sequelae of such procedures resulted in feet that were stiff, painful, and often still deformed.

To avoid the damage to articular surfaces caused by crushing the bones of the foot during forcible manipulation, Alexander Ogston (1844–1929) of Aberdeen curretted out the cancelous centers of tarsal bones so that they would collapse and reshape themselves without excessive pressure.[34] The technique of this procedure, called *excochleation*, was well described by Arthur Steindler.[35] Ogston was an early student of surgical bacteriology and was responsible for isolating, characterizing, and naming the genus *Staphylococcus*.[36]

The fact that Ogston's paper, published in 1902, was accompanied by a group of radiographs of the foot should come as no surprise. Like the hand, the foot was easily immobilized for the long exposures required by the early equipment and did not have a large amount of soft tissue. Charles A. Morton of Bristol was taking skiagraphs of the feet of children with clubfeet as early as 1897.[37] In 1917 Isadore Zadek and E. L. Barnett advocated the use of radiographs to determine whether or not a correction of the deformity had been obtained.[38] Fifteen years later, John McCauley and Arthur Krida, in an excellent article on the treatment of clubfeet, concluded that "a true conception of the existence or non-existence of equinus in a clinically over-corrected club foot can best be demonstrated by x-ray."[39] Standards for the







Figures 3.22–3.25 The application of the Thomas wrench in the treatment of clubfeet. Top left: the application to the inverted adducted forefoot; Top right: correction of the adducted forefoot; Bottom left: correction of inversion and equinus; Bottom right: the splint used following manipulation. From John Ridlon and Charles E. Eikenbary, "Congenital Clubfoot," offprint from *Illinois Med J* February (1906): 4–5.

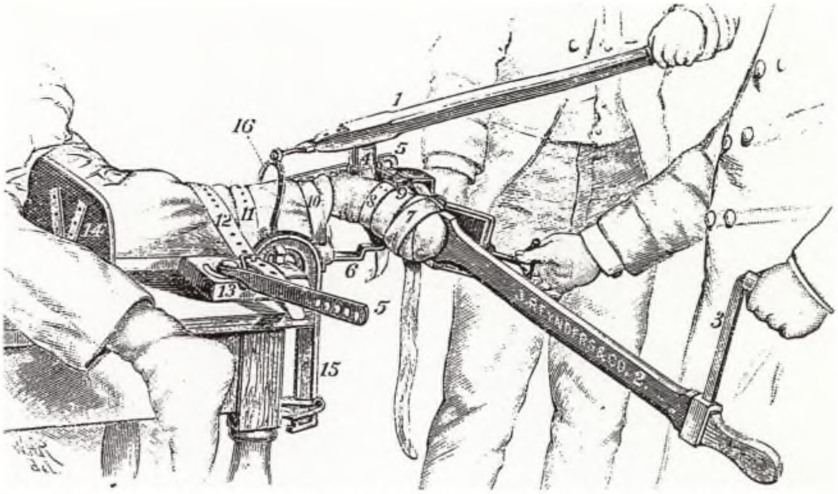


Figure 3.26 The "clubfoot machine" used by A. M Phelps. Apparatus of this type were commonly employed under anesthesia to obtain forceable correction of the deformity. From A. M. Phelps, "The Present Status of the Open Incision Method for Talipes Varo-Equinus," *Med Record* 38(1890): 595.

technique and analysis of radiographs of congenital abnormalities of the feet were established by Lawrence Davis and William Hatt in 1955.[40]

The introduction of subcutaneous tenotomy of the Achilles tendon had focused the attention of surgeons on the surgical treatment of clubfeet. While this operation was very successful in the correction of equinus deformities due to poliomyelitis, cerebral palsy, and old injuries, it was not a panacea for the patient with the congenital clubfoot. To be successful, the forefoot adduction and inversion had to be corrected completely before correction of the equinus deformity could benefit the patient. For this reason operations were extended to include tenotomies of other tendons, particularly the anterior tibial tendon and incisions in the capsules of the talar joints. Sometimes these operations could become very extensive. In 1890 Phelps outlined his approach to the surgical correction of clubfoot, based on an experience of 161 operations on 93 patients, as follows:

The method which I propose to govern the management of club-foot, requiring operative work is this:

1. *Exclude all cases which, by manipulation or force can immediately or in a reasonable length of time be cured; then the following rule should be followed.*
2. *Cut the contracted parts as they first offer resistance, cutting in the order of those parts which first contracted when the deformity was produced.*

The operator will then procede, after strong manipulation or force is applied with a club-foot machine or with the hands, to subcutaneously divide, first the teno-Achilles. If the skin is not short, subcutaneous tenotomy in the sole of the foot will usually suffice. If the skin is short, an open incision one-fourth the distance across the foot can

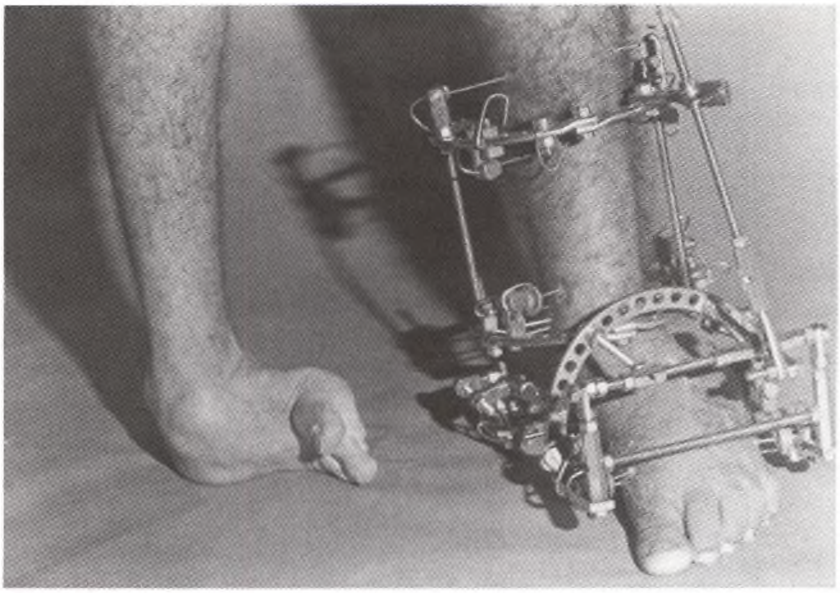


Figure 3.27 Correction of an old clubfoot deformity using the Ilizarov method. Reprinted with permission. From S. A Green and D. M. Wall, "The Ilizarov Method: Transfixion Wire Technique," *Mediguide to Orthopaedics* 1989: 8(6): 1. Copyright © 1989 Lawrence DellaCorte Publications, Inc.

be made, beginning directly in front of the inner malleolus and carried down to the inner side of the neck of the astragalus. Through this incision the following tissues can be cut, if they offer strong resistance, in the order given: a) Tenotomy of the tibialis posticus; b) division of the abductor pollicis; c) division of the plantar fascia through the wound; d) division of the flexor brevis muscle; e) division of long flexors; f) division of deltoid ligament, all its branches.

3. *Linear osteotomy through the neck of the astragalus.*
4. *Resection of a wedge-shaped piece of bone from the body of the os calcis, the point meeting the linear osteotomy through the neck of the astragalus. The foot will now swing to a straight position.*[41]

Almost all of the operations developed in the next hundred years for the treatment of clubfeet are included in this litany.

Phelps was born in Vermont and graduated from the College of Medicine of the University of Michigan in 1873. He traveled and studied extensively in Europe before returning to New York, where he rose to become the professor of orthopedic surgery at the University of the City of New York and the Post Graduate Medical School and Hospital.

E. P. Brockman (1894–1977) of London considered the best salvage operation, after unsuccessful treatment for the painful, stiff, and deformed clubfoot, to be the triple arthrodesis.

I still believe that when all other methods of treatment have failed, and arthrodesis of the subastraguloid and mid tarsal joints, removing at the same time sufficient bone at these joints to produce a correction, is the best and most lasting method of treatment.[42]

Figure 3.28 Edward Hickling Bradford (1848–1926). From *SGO* 45(1927): 564.

The number of such radical surgical procedures for the correction of the deformities gradually decreased as more and more emphasis was placed upon the early treatment while the clubfoot was still amenable to nonoperative treatment and early care became available through organized crippled children's services. For example, in the Club Foot Clinic at the New York Orthopedic Dispensary and Hospital during 1942 and 1943, 2,894 patients were treated for clubfeet.[43] Of these patients, only 30 were admitted to the hospital for operation and only 40 operations were performed.

There has been continuing dissatisfaction with the results of the treatment of clubfeet. While there is little question that the initial treatment of the infant should be the classic methods of regular manipulation and retention of the position gained in a plaster of paris dressing, various surgical options are available and the indications and timing of the procedures are still being debated.[44] The use of the Ilizarov distractor for the treatment of severe clubfoot deformities reemphasizes that these deformities will yield to persuasive pressure exerted continuously over long periods[45] (figure 3.27).

Another great contributor to the field of orthopedics was Edward Hickling Bradford (1848–1926) (figure 3.28). Bradford was a graduate of the Harvard Medical School. After receiving further postgraduate training at the Massachusetts General Hospital, he spent two years studying in Europe.[46] After a period of working as a general practitioner, he became interested in orthopedics, studying with Charles Fayette Taylor at the New York Orthopaedic Dispensary before retuning to Boston and an association with Buckminster Brown. Appointed as the first John Ball and Buckminster Brown Professor of Orthopaedic Surgery at the Harvard Medical School, he served in this position from 1903 to 1912. During World War I, he was dean of the medical school. As a teacher Bradford wrote extensively on subjects of orthopedic interest and raised a fine group of young associates around him. Bradford's comment from his 1889 article entitled "Treatment of Club-Foot" remains very appropriate.

The literature of the treatment of club-foot is, as a rule, that of unvarying success. It is often as brilliant as an advertising sheet, and yet in practice there is no lack of half-cured or relapsed cases,—sufficient evidence that methods of cure are not universally understood.

It has been said by some writers that the treatment of club-foot is one of the most unsatisfactory undertakings in surgery. The reverse has also been said; namely, that nothing is so gratifying as the correction of talipes equino-varus. Both statements are true; and in explanation of the contradiction it may be said that imperfect methods give extremely unsatisfactory results in club-foot, while success is *sure to reward the proper methods thoroughly carried out. In no branch of surgery can a cure be more confidently promised than in the treatment of club-foot, and in few surgical undertakings do half measures occasion greater annoyance.*[47]

The deformity associated with congenital dislocations of the hip, in contrast to that of clubfeet, is not readily apparent at birth. Early diagnosis, so important in the success of treatment, is difficult, especially when the deformity was bilateral. Frequently, unrecognized and untreated cases appear to have only limited disability. In the Cree-Ojibwa population in Canada, a group known to have a high incidence of the deformity, an evaluation by J. M. Walker of 450 typical cases of congenital dislocation of the hip showed little functional impairment int the normal activities of daily living.[48] Hippocrates noted that such dislocations occurred and mentioned that in such patients the shortening of the leg was in the thigh rather than the lower leg.[49] Beyond this, he had little to say. Nicolas Andry also recognized that such a condition existed.

The Thigh or Leg may be luxated from the Womb, by different Causes, as well as other Parts, such as the Shoulder, the Elbow, the Heel, the Jaw, the Vertibrae. Some Children have been born with both their Thighs luxated, and have remained Cripples. I shall not enter upon a Discussion of those different Causes: I shall only advise you, wherever the Dislocation is observed, immediately to have recourse to the Hand of the Surgeon: for if this is neglected, a Callus will be formed in the dislocated Part, which will render the Cure absolutely impossible.[50]

Recourse to the hand of a surgeon, as recommended by Andry, would have availed little, for until the beginning of the nineteenth century the anatomy of the condition was so poorly understood that treatment was not considered.

Giovanni Battista Palletta (1747–1832), who preceded Giovanni Battista Monteggia (1762–1815) as the chief surgeon at the Ospedale Maggiore in Milan, is credited with the first anatomical description of a congenital dislocation of the hip.[51] He described the form of the head of the femur, the acetabulum, the capsule, and the ligaments of a fifteen-day-old boy with bilateral dislocations.[52] However, Guillaume Dupuytren was the first to give an extensive report of the pathological changes associated with congenital dislocation of the hip based upon multiple dissections.[53]

The appearances I have found in such subjects are the following: All the muscles which have their attachment either above or below the acetabulum were drawn up towards the crest of the ilium. Amongst these muscles some were well developed, whilst others were attenuated and slightly atrophied; the former were those which had *preserved their action, the latter those the action of which had been cramped and limited, or even entirely negatived by the altered relation of their attachments. Of the latter class some few were reduced to a sort of yellowish fibrous tissue, amid which the eye sought in vain for any trace of muscular fibre. The upper part of the thigh preserves, in these cases, its natural form and dimensions, with the single exception of the upper and inner part of the head of this bone, which I have remarked has sometimes lost a little of its roundness, a circumstance which appears due to the friction it has been subjected to, by contact with a surface unsuited for articulation. The cotyloid cavity is either altogether absent, or presents only a small osseous, irregular prominence, where neither trace of diarthrodial cartilage nor vestige of synovial or other capsule, nor fibrous margin is to be found; but which is surrounded by some tough cellular tissue, and covered by the muscles which are inserted into the smaller trochanter. Once, in two or three subjects which have been submitted for my examination, I met with the round ligament of the joint very much elongated, flattened above and, as it were, worn at certain points by the pressure and friction of the head of the femur.*

The head of the bone itself is lodged in a hollow, somewhat analogous to that which is developed around it in accidental dislocations upwards and outwards which have remained unreduced. This new cavity, which is very superficial and almost without a rim, is situated in the external iliac fossa, that is to say, above and behind the acetabulum, at an elevation proportioned to the shortening of the limb, or to the ascent of the head of the femur, which amounts to the same thing. In fact, the only perceptible difference in this respect, that I have been able to detect between these congenital cases, and accidental dislocations of old date or those which were spontaneous, is that in the former, the arrangement of the parts appears to have subsisted for a longer term, and gives the impression of its having been the primitive condition, or that which was assumed at the very earliest period of existence.

What then can account for a dislocation, of which neither disease nor violence can be assigned as the cause, at least as far as observation can inform us? Can it be the result of a disease affecting the infant whilst still in its mother's womb, but cured before its birth? or may external violence or muscular effort produce the displacement of the head of the femur, and a natural process of obliteration remove the traces of the then useless acetabulum? or lastly, does nature forget her work, and leave the head of the femur unprovided with a cavity to play in; or, as M. Breschet thinks, does some obstacle to the normal evolution of the bones constituting the acetabulum render this cavity imperfect? To these difficult questions I have no solution of my own to offer.[54]

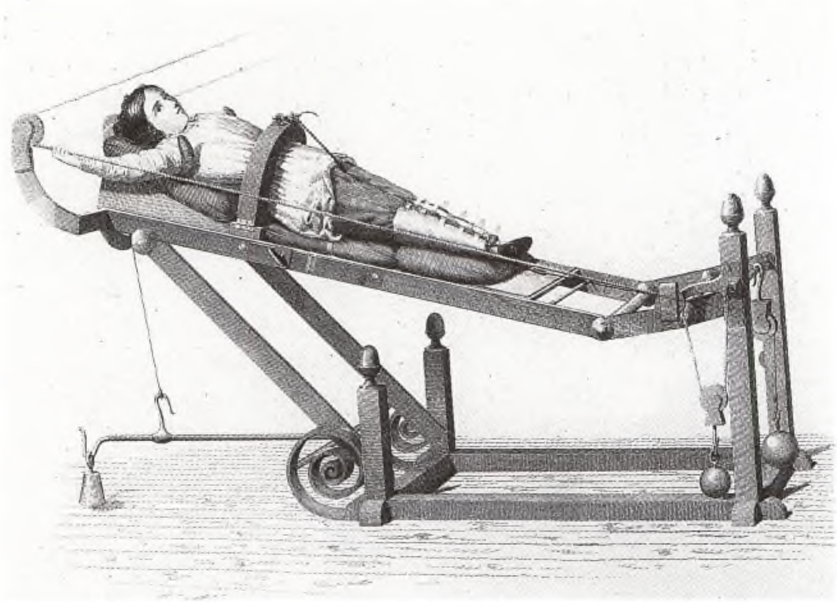


Figure 3.30 The traction apparatus used by Pravaz to reduce a congenital dislocation of the hip. Note that the patient is not an infant. From Pravaz, *Traité théorique et pratique des luxations congénitales du fémur* (Lyon: Guilbert et Dorier, 1847), pl. 7.

Figure 3.29 Charles Gabriel Pravaz (1791–1853). From "Charles Gabriel Pravaz, Inventor of the the Hypodermic Syringe," *Clin Med Surg* 43(1936): facing p. 475

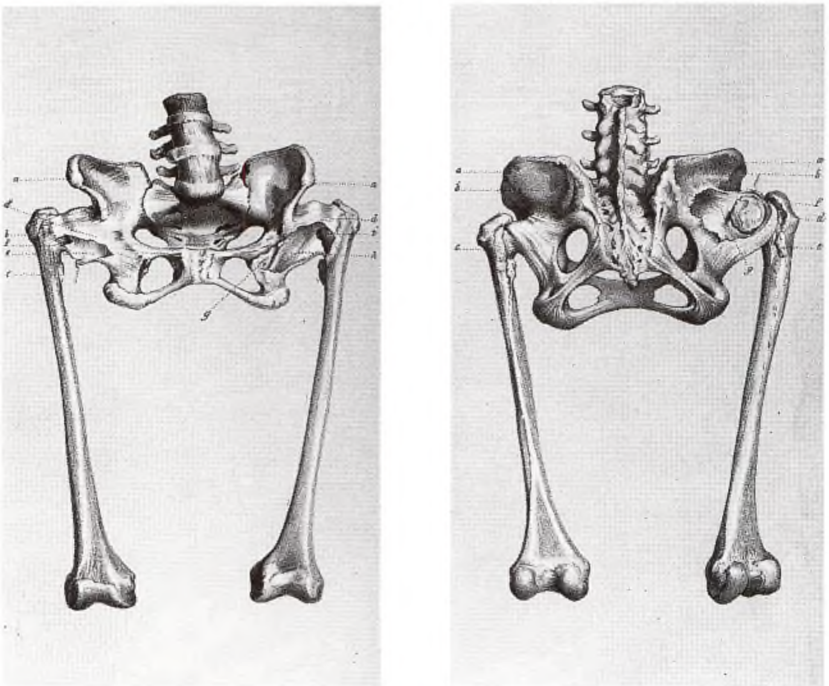
Dupuytren's report correlated the clinical condition closely with the pathology. While he did not believe that the condition was amenable to treatment, his exposition of its pathology was closely followed by the first successful reduction of a congenital dislocation of the hip by his countryman, Charles Gabriel Pravaz.

Charles Gabriel Pravaz (1791–1853) (figure 3.29), the son of a physician, was born in Lyon. He served as a soldier in Napoleon's army and was present at the battle of Waterloo. He then studied medicine in Paris, where he was granted his medical degree in 1824. He was associated with Jules Guérin in an orthopedic institute in Paris, but left this partnership after a year to found l'Institut Orthopédique et Pneumatique de Lyon. Here he pursued his work on the treatment of deformities in which he used methods similar to those of Delpech. He was also interested in the treatment of vascular aneurysms, using electric currents and the injection of ferrous chloride as coagulants. It was this work that gave rise to the belief that Pravaz was the inventor of the hypodermic syringe, an opinion no longer tenable.[55] In 1847 Pravaz published a monograph, *Traité théoretique et pratique des luxations congénitales du fémur*, which was given a prize by the Academy of Science.[56] This monograph contained his ideas on the treatment of congenital dislocations of the hip and a report of nineteen patients.

Bruno Valentin points out that Guillaume Jalade-Lafond (b. 1805) and François Humbert (1776–1850) had attempted to reduce a congenital hip prior to Pravaz: the first by gentle traction on an oscillating bed; the second by forcible traction over a period of fifty-five minutes.[57] However, Pravaz was the first to be credited with a successful reposition of such a dislocation. His method consisted of continuous traction with increasing abduction and local pressure over the greater trochanter (figure 3.30). Eight to ten months of traction were required to bring the head of the femur into apposition with the acetabulum. Weight-bearing was not allowed for a prolonged period and the rehabilitation, or after-care, extended for two years. After Pravaz had made his preliminary presentations to the Academy of Science in 1838 and 1839, a commission was appointed consisting of Philippe-Frédéric Blandin (1798–1849), Jean-Baptiste Nacquart (1780–1853), Louis Joseph Sanson (1790–1883) and Pierre-Nicolas Gerdy (1797–1856) to investigate his results. This report, composed by Gerdy, was published in 1840 and, though written in a tone of approval, also reported that the limp persisted, the limb was still somewhat shortened, the greater trochanter was still prominent, and the motion of abduction was still limited.[58]

Jules Guérin immediately modified the method introduced by Pravaz to include subcutaneous tenotomy. In 1841 he suggested the following procedures: (1) a period of preliminary traction, (2) subcutaneous tenotomy of those muscles that were not sufficiently ellongated by traction, (3) continuation of traction to elongate the ligamentous structures, (4) manipulation to achieve reduction, and (5) treatment to maintain reduction.[59] One of the ways in which he attempted to promote a stable reduction was to scarify the superior capsule and the lateral wall of the ilium above the top of the acetabulum using a tenotomy knife in order to produce adhesion of the capsule to the ilium. B. E. Brodhurst in London reported success with such a procedure in 1866 and commented that such an operation was not necessary in children under the age of two years.[60] Unfortunately, because of delay in diagnosis few, if any, children of this age came to the attention of surgeons.

A report of these developments in the diagnosis and treatment of congenital dislocation of the hip became available in the United States with the publication in 1850 of a small book by John Murray Carnochan (1817–1887) entitled *A Treatise on the Etiology, Pathology and Treatment of Congenital Dislocations of the Head of the Femur.*[61] This book contained many interesting plates and a thorough discussion of the work of Pravaz (figures 3.31–3.35). Carnochan was born in Savannah, Georgia, and educated in Edinburgh. He was granted his medical degree from the College of Physicians and Surgeons of New York in 1836 and then went to Paris, where he studied for several years. After his return to New York he developed a large surgical practice and in 1851 was made professor of surgery at the New York Medical College. It is unclear if Carnochan ever attempted or succeeded in reducing a congenital dislocation of the hip.

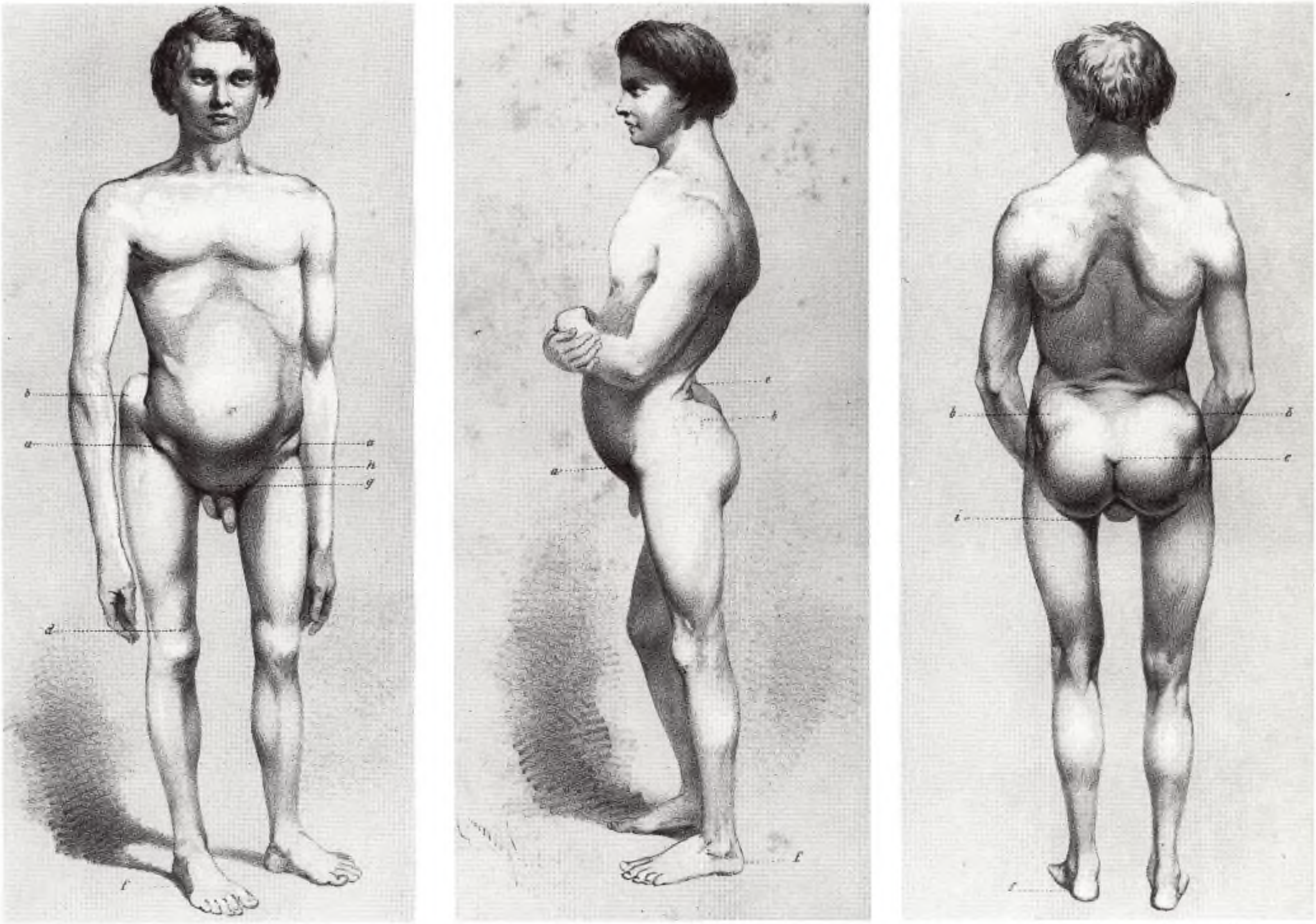


Figures 3.31–3.32 Anterior and posterior views of a dissection of a patient with bilateral congenital dislocations of the hip. From John Murray Carnochan, *A Treatise on the Etiology, Pathology and Treatment of Congenital Dislocation of the Head of the Femur* (New York: S. S. & W. Wood, 1850), pls. 6–7.

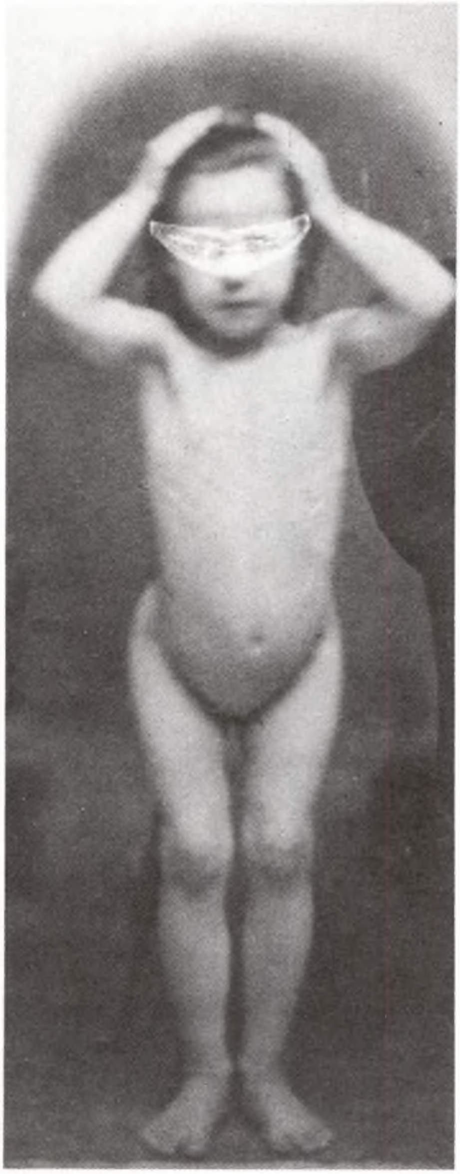
Buckminster Brown (1819–1891) of Boston spent the winter of 1845–46 in Paris as an observer in the clinic of Guérin, where he too became aware of the methods being used to treat congenital dislocation of the hip. In 1885 he published a complete report of a case, accompanied by photographs, of a four-year-old girl with bilateral congenital dislocations of the hip.[62] She was treated in traction in bed for thirteen months and then had a long period of rehabilitation (figures 3.36 – 3.39). The long-term result was very satisfactory (figures 3.40 – 3.41).

Another Boston surgeon, Henry Jacob Bigelow (1818–1890), made a great contribution to the treatment of congenital dislocations of the hip in a somewhat tangential manner. In his book, *The Mechanism of Dislocation and Fracture of the Hip with the Reduction of the Dislocations by the Flexion Method*, published in 1869, Bigelow emphasized for the first time the importance of the thickened portion of the anterior capsule of the hip joint, now known as the Y-ligament of Bigelow, and its importance in the reduction of traumatic dislocations of the hip.[63] In discussing the reduction of a dislocation of the hip by rotation, Bigelow stated:

Flex the thigh and abduct or circumduct it outwards, at the same time rotating it outwards. The head of the bone, revolving about the great trochanter, which is fixed by the the outer branch of the Y ligament, rises over the edge of the socket into its place, unless the



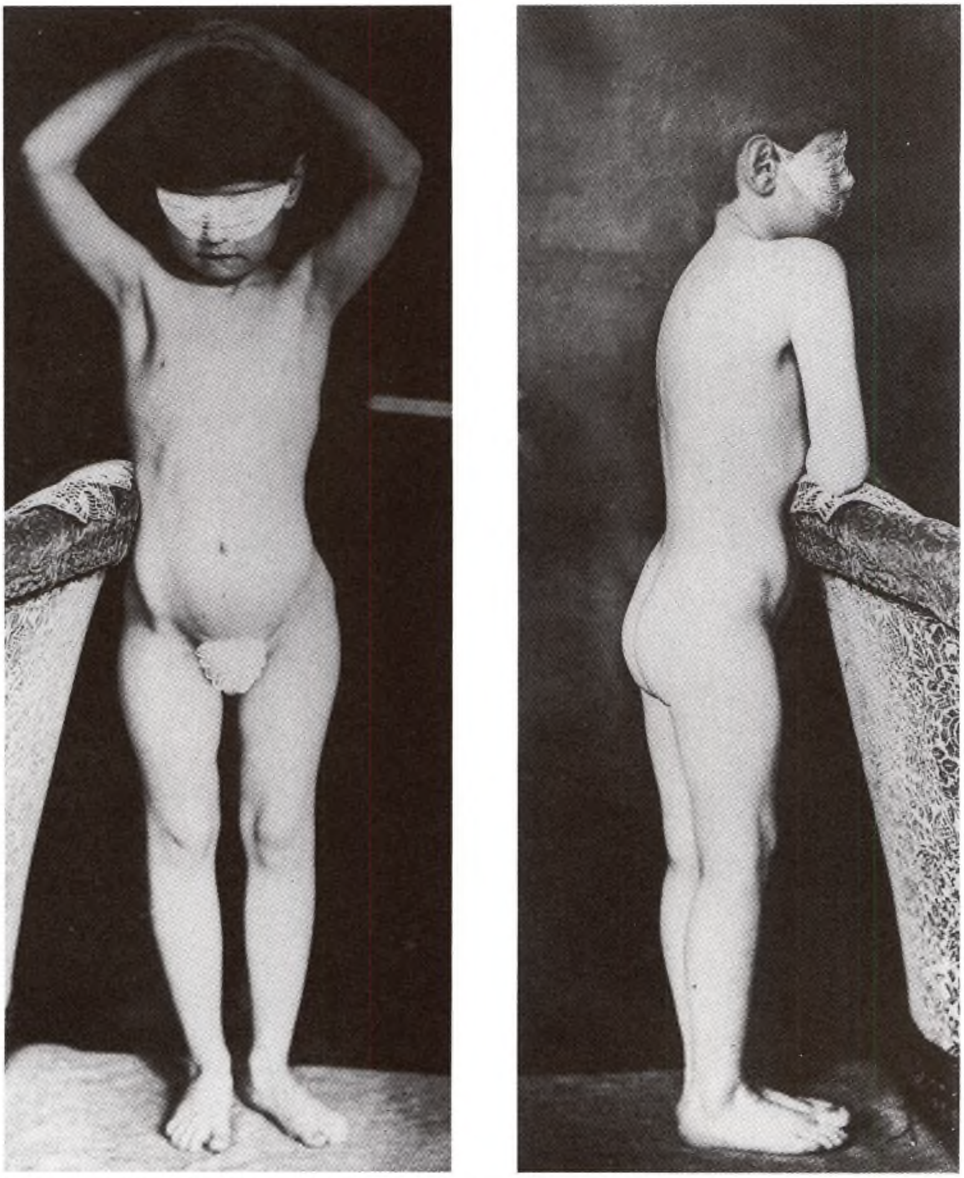
Figures 3.33–3.35 Views of a young man with bilateral congenital dislocations of the hip. From Carnochan, *A Treatise on the Etiology*, pls. 1–2, 4.

Figures 3.36–3.37 Views of the four-year-old girl treated by Buckminster Brown for bilateral congenital dislocations of the hip. From Brown, "Double Congenital Displacement of the Hip: Description of a Case with Treatment Resulting in a Cure," *Boston Med Surg J* 62(1885): 541–46, pls. 1–2.

Figure 3.38 The traction system used by Buckminster Brown. From Brown, "Double Congenital Displacement of the Hip," 541–46, pl. 3.

Figure 3.39 The "walker" used by Buckminster Brown, which was very similar to the one used by Pravaz. From Brown, "Double Congenital Displacement of the Hip," 541–46, pl. 5.



Figures 3.40–3.41 Views of the patient two years and three months after beginning the treatment: "The child's walk is normal, and she enjoys walking; she steps with natural firmness and vigor. Like other children she takes especial pleasure in running." From Brown, "Double Congenital Displacement of the Hip," 541–46, pls. 7–8.

capsule is interposed, in which case enlarge the opening, as in the third method. This is a very effective manoeuvre for the reduction of the dorsal luxatons, and has been described in the words, "Lift up, bend out, roll out." [64]

Figure 3.42 Albert Hoffa (1859–1907). From Georg Hohman, "Würzburg die Wiege der deutschen Orthopädie," *Arch orthop Unfall-Chir* 45(1963): 563–72.

Bigelow's analysis of the types of dislocations and the methods of reduction provided orthopedists with the information that they needed to improve their methods of reducing congenital dislocations of the hip by closed manipulation.

It is not surprising that, with the development of anesthesia and antiseptic-aseptic surgical techniques, surgeons attempted a direct, open surgical reduction of a congenital dislocation of the hip. In 1880 Alfonso Poggi (1848–1930) of Bologna reported that he had operated upon a twelve-year-old girl with a unilateral and untreated congenital dislocation of the hip.[65] The misshapen head was rounded and reduced into a deepened acetabulum. Albert Hoffa (1859–1907) (figure 3.42) was to develop and popularize the operation of open reduction of a congenital dislocation of the hip.[66] Hoffa's operation was well described by Edward Bradford and Robert Lovett.[67] Hoffa believed that for the best results the operation should be carried out early, that is, in young children, and did not advise carrying out the operation in older children or adults.[68]

Figure 3.43 Adolf Lorenz (1854–1946). From Nils Silfverskiold, "Adolf Lorenz in Memoriam," *Acta orthop scand* 16(1946): 101.

Hoffa was born in South Africa but educated in Germany. He began his career by establishing a private orthopedic clinic in Würzburg in 1886. Following the death of Julius Wolff, the founder of the first orthopedic clinic in Berlin, Hoffa succeeded him and became the leading orthopedic surgeon in Germany. His death at the age of only forty-eight cut short a brilliant career.

Hoffa's operation was modified by his rival in Vienna, Adolf Lorenz (1854–1946) (figure 3.43), who for a time was a great advocate of the operative reduction of congenital dislocations of the hip.[69] This changed abruptly when Lorenz was forced to abandon operative surgery because of a sensitivity to carbolic acid that produced a disabling contact dermatitis on his hands.[70] Lorenz immediately became the champion of the closed, *unblutig* (bloodless) method of reducing congenital dislocations of the hip, which was based on Bigelow's observations. Agostino Paci (1845–1902) of Pisa had described the closed method of reduction in 1888, and Lorenz popularized its use.[71] Using this method Lorenz gained worldwide attention, especially during his extensive travels in the United States in 1902–3. John Ridlon, who collaborated with Lorenz while he was in Chicago, concluded, however, on the basis of twenty-nine cases done by Lorenz and sixty-five of his own, that in only ten to twenty percent of the patients was an anatomical reduction obtained.[72]

Lorenz, the son of a harness maker and peasant's daughter, was born in Silesia. He obtained his secondary education in a

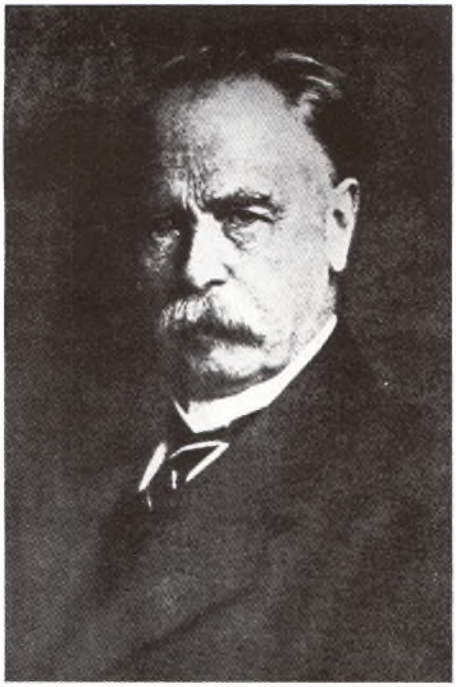


Figure 3.44 Friedrich Trendelenburg (1844–1924). From *Med Classics* 4(1940): facing p. 923.

Figure 3.45 Heinrich Hilgenreiner (1870–1953). From Obituary: "Prof. Dr. Hilgenreiner," *Zeit orthop Chir* 84(1954): 502.

Benedictine monastery, where he was a choir boy. He began to study medicine at the age of twenty at the medical school in Vienna. Following his graduation he worked in the First Surgical Clinic of the Allegemeines Krankenhaus under the direction of Eduard Albert. After a promising start in operative surgery, his banishment from the operating room (because of his dermatitis) may have been a blessing in disguise, for it led to the formation within the hospital of its first orthopedic clinic.

In 1885 Lorenz published a thorough exposition of the problem of congenital dislocations of the hip.[73] At that time the diagnosis was based on (1) the prominence of the greater trochanter and its displacement above Nélaton's line, (2) asymmetrical gluteal folds, (3) apparent femoral shortening, and (4) limitation of abduction. In bilateral cases, lordosis was an important additional finding. The characteristic gait of a patient with a congenital dislocation of the hip was described by by the German surgeon Friedrich Trendelenburg (1844–1925) (figure 3.44) in 1895.[74] In the third edition of his book *Die angeborne Luxation des Hüftgelenkes*, published in 1920, Lorenz added a section on the use of the X-ray in diagnosis, and while discussing the complications of the treatment called attention to a radiograph showing aseptic necrosis of the head of the femur.[75] With only minor exceptions, all of the illustrations and radiographs used by Lorenz and his contemporaries were of children of five years of age or older.

As early as 1900 Max Schede (1844–1902) in Bonn had published a small monograph on the radiographic anatomy of congenital dislocations of the hip. The quality of the images was surprisingly good and his understanding of the limitations of the technique, even at this early stage, was excellent.

The roentgenograms show us a lot, to be sure, but not everything. The proximal femoral epiphysis is well seen, but in younger children the surrounding structures are not well visualized, i.e. the acetabular rim, the limbus, the ligamentum teres, the contents of the acetabulum and especially the relationships of the capsule.[76]

It was Heinrich Hilgenreiner (1870–1953) (figure 3.45) who did the most to define the radiographic anatomy of the patient with a congenital dislocation of the hip. Hilgenreiner was educated at Carl's University in Prague.[77] He had postgraduate training in surgery and joined the faculty in 1907. He was decorated for his service in the Austrian army during World War I. Although he was a surgeon, his major interest was in patients with congenital dislocation of the hips. In 1925 he defined the radiographic criteria for establishing the diagnosis of a congenital dysplasia or dislocation of the hip.[78] Hilgenreiner's Lines, which measure the acetabular angle, have become well known to all orthopedic surgeons and radiologists (figure 3.46). He was an

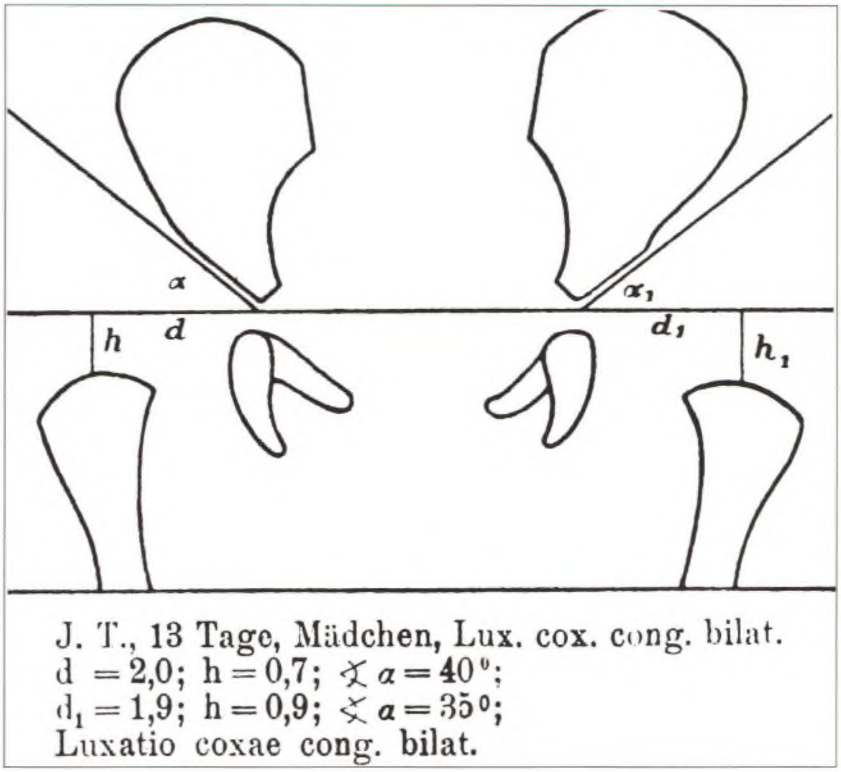


Figure 3.46 Hilgenreiner's Lines. From H. Hilgenreiner, "Zur Frühdiagnose und Frühbehandlungen der angeborenen Hüftgelenkverrenkung," *Med Klin* 21(1925): 1425–29, figure 3.

Figure 3.47 George Perkins (1892–1979). From "In Memoriam: George Perkins, 1892–1979," *J Bone Joint Surg* 62B(1980): 248.

Figure 3.48 Perkins's Line. From George Perkins, "Signs by Which to Diagnose Congenital Dislocation of the Hip," *Lancet* 1(1928): 648–50, fig. 2.

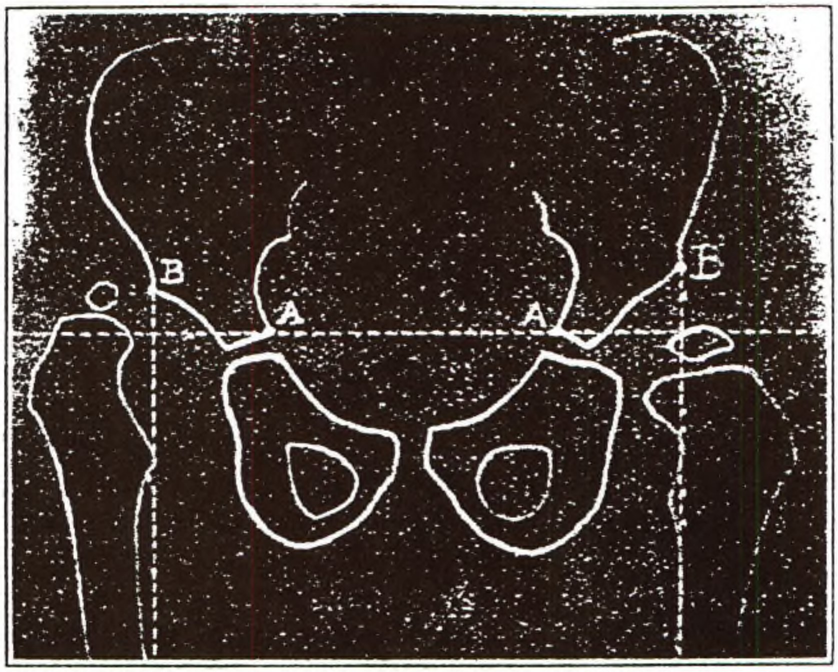
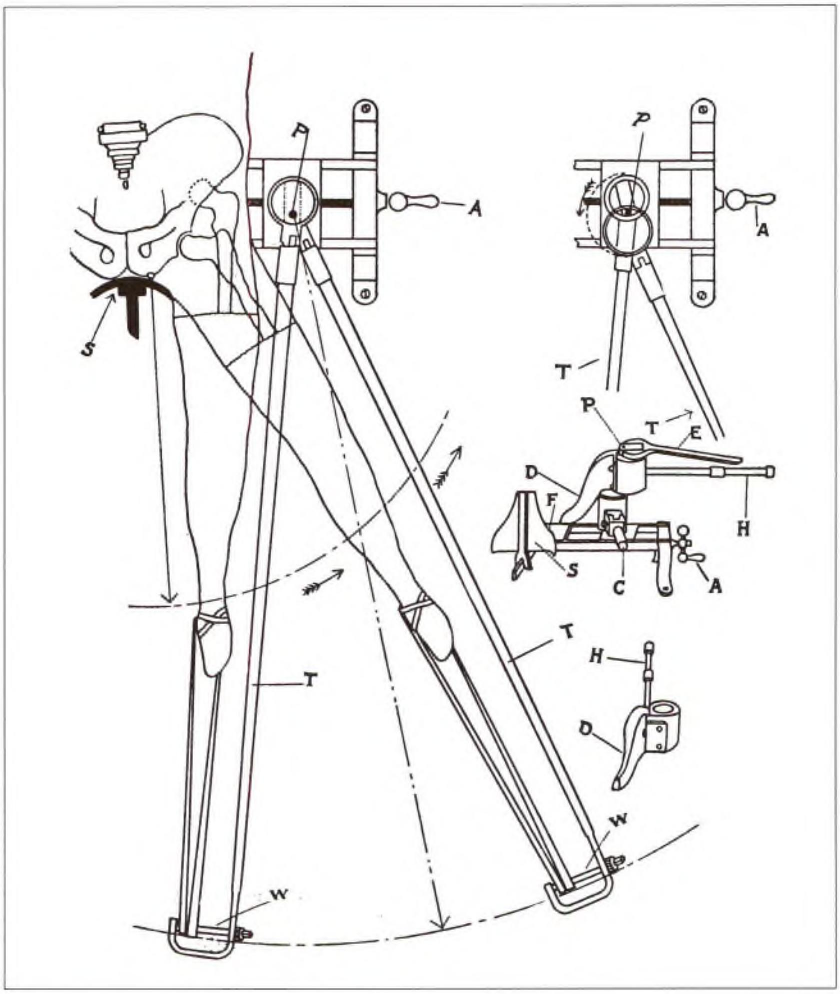


Figure 3.49 The machine devised by a Boston lawyer for reducing dislocations of the hip. From John Ridlon, "The Bartlett (Boston) Machine for the Reduction of Congenital Dislocations of the Hip," *Chicago Med Record* 27(1905): 630.



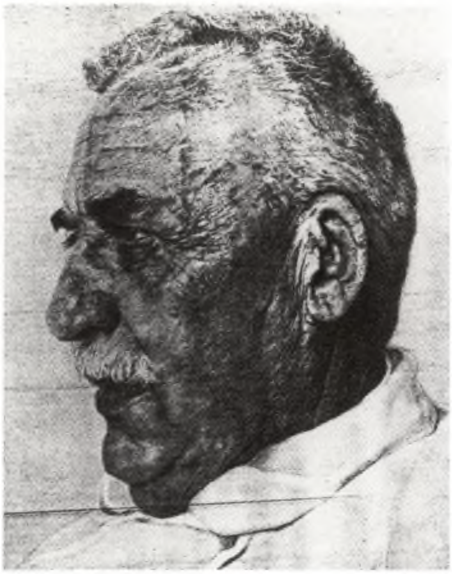


Figure 3.50 Alfred Schanz (1890–1972). From *Zeit orthop Chir* 51(1929): 1.

important advocate of early diagnosis and early treatment of congenital dislocations of the hip. At the end of World War II he was imprisoned briefly and was forced to flee to Austria before being allowed to return to Czechoslovakia shortly before his death. He paid the penalty of many radiographic pioneers, having developed a severe X-ray dermatitis on his hands.

Hilgenreiner's counterpart in England was George Perkins (1892–1979) (figure 3.47). Perkins was born in London and educated at Oxford University and St. Thomas's Hospital. During World War I he served with the British in Africa and became a prisoner of war in Germany. He spent some time after the war at the Royal National Orthopaedic Hospital before moving on to St. Thomas's, where he was an essential element in the development of the orthopedic department. In 1928 he thoroughly discussed the clinical and radiographic diagnosis of congenital dislocation of the hip. Among his observations was a measure of lateral displacement of the proximal femoral epiphysis using a perpendicular line dropped from the lateral edge of the acetabulum, what is now known as *Perkin's Line*[79] (figure 3.48). The general use of arthrography in the evaluation of congenital dislocations of the hip followed approximately ten years later.[80]

The difficulties of carrying out a closed reduction of a congenital dislocation of the hip in a child of three or four by manipulation alone led directly to the use of mechanical "assistants," such as the machine designed by the Boston lawyer, Ralph W. Bartlett, in 1903. This apparatus would

effectually pull the entire limb directly downward to any desired extent, rotate or circumduct, abduct or adduct, flex or extend, in fact, execute any motion of the hip in any direction while the pull was maintained and at the same time make pressure against the greater trochanter inward and downward toward the acetabulum[81][figure 3.49].

It is not surprising that John Ridlon reported he had encountered fractures in the trochanteric area of the femur complicating reduction of congenital dislocations by both manipulation and by use of the Bartlett machine.[82] Such fractures were not uncommon. Lorenz himself had experienced this complication and the observation of these patients led him to develop the bifurcation osteotomy of the upper end of the femur.[83]

In the bifurcation osteotomy, the position of the unreduced head of the femur remained unchanged while an osteotomy of the femur was carried out at the level of the acetabulum.[84] The proximal end of the distal fragment was placed into the acetabulum. As time passed, the spike placed in the acetabulum atrophied and disappeared; the end result was a pelvic support osteotomy. This operation was gradually replaced by the osteotomy devised by Alfred Schanz (1870–1931)[85] (figure 3.50). In

Figure 3.51 Arthur Bruce Gill (1876–1965). From *J Bone Joint Surg* 48A(1966): 394.

Figure 3.52 Robert Bruce Salter. Courtesy of Dr. Salter.

this operation the femur was divided somewhat more distally at the level of the ischial tuberosity.[86] This was the generic pelvic support osteotomy.[87] Both the Lorenz and Schanz osteotomies had the effect of reducing the degree of lordosis and providing pain relief.

Schanz was born in Plauen, Germany, and studied medicine in Jena, Leipzig, and Berlin.[88] His postgraduate training in orthopedic surgery was obtained in Würzburg, where he was considered to be the best of Hoffa's students. In 1897 he moved to Dresden, where he developed regional programs for the treatment of the crippled. Because of his prolific publications he became one of the best known of his orthopedic contemporaries.

To overcome the difficulty of reducing a congenital dislocation of the hip at an open operation, an osteotomy of the femoral shaft was sometimes used.[89] After shortening the femur by resecting a portion of the shaft, E. W. Hey Groves internally fixed the femur using an intramedullary bone peg.[90]

For congenital dislocations of the hip in older children, Paul C. Colonna (1892–1966) carried out an arthroplasty in which the head of the femur was reduced either into the old acetabulum, which was cleared of its contents, or into the false acetabulum, which was deepened by curretment.[91] For the older patient with a painful unstable hip, arthrodesis was always an option.[92]

The idea of extending the roof of the acetabulum outward by means of a shelf in contrast to deepening it, was advanced by Franz Koenig (1832–1910) in 1871.[93] The technique of placing a bone graft over the uncovered lateral head of the femur took a long time to evolve. Hans Spitzy in Vienna and Fred H. Albee in New York were early proponents of the operation.[94] It was Arthur Bruce Gill (1876–1965) of Philadelphia (figure 3.51) who became the strongest advocate of the "shelf operation," using it in almost every case of incompletely reduced dislocation.[95] Gill was born in western Pennsylvania and graduated from the University of Pennsylvania College of Medicine in 1905.[96] His teachers interested him in orthopedic surgery and in 1920 he succeeded Gwilym G. Davis as professor of orthopedic surgery at the University of Pennsylvania. His life was dedicated to the care of crippled children and adults, for whom he developed several operative techniques. He was president of the American Academy of Orthopaedic Surgeons in 1938 and the American Orthopaedic Association in 1944.

The operations designed to deepen the acetabulum by extending the acetabular roof over the head of the femur gradually gave way to a new group of operations that deepened the acetabulum through performing osteotomies of the innominate bone in which the acetabulum was situated. Although both Karl Chiari and Paul Pemberton developed operations of this type,[97] the

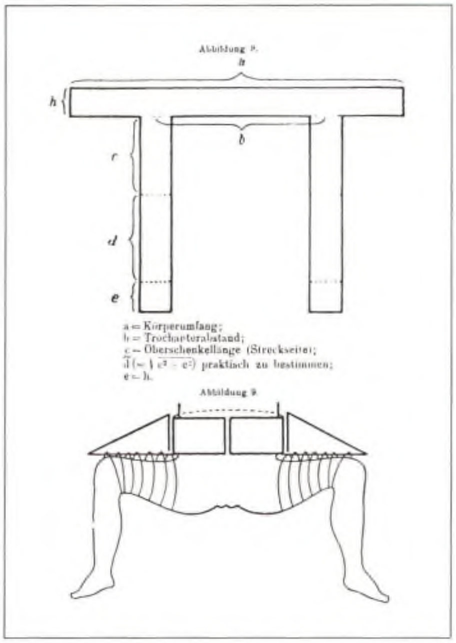


Figure 3.53 Hilgenreiner's pasteboard abduction splint. From Hilgenreiner, "Zur Frühdiagnose und Frühbehandlung," 1428.

most popular was the innominate osteotomy designed by Robert B. Salter (b. 1924) of Toronto[98] (figure 3.52). Salter, a sixth-generation Canadian, graduated from the University of Toronto. His orthopedic training was obtained at his alma mater and in England. In 1955 he was appointed to the staff of the Hospital for Sick Children in Toronto, becoming chief of orthopedic surgery two years later. It is in this hospital and its research institute that he has spent his career. In addition to his work on the complications and treatment of congenital dislocations of the hip, Salter is known for his classification of epiphyseal injuries and his research, which provided the impetus for the clinical use of continuous passive motion in the treatment of a wide variety of orthopedic conditions. As a professor at the University of Toronto, Salter has had a wide influence on students from Canada, the United States, and other countries throughout the world.

All of the surgical interventions carried out on children with congenital dislocations of the hip were palliative procedures and, in spite of the claims of their creators, were not completely and regularly successful. They were all designed for children over two years old or older, the age that most patients were brought to the orthopedist for treatment. The plaster of paris dressings commonly employed for retention of the reduced hips were not practical for use in the very young. To improve results it was necessary to make the diagnosis as soon after birth as possible and to institute treatment immediately.

Heinrich Higenreiner was one of the first to advocate such a program. In 1925, in his paper entitled "The Early Diagnosis and Early Treatment of Congenital Dislocations of the Hip," Hilgenreiner concluded:

> 1. *Every congenital dislocation or subluxation of the hip should be treated as soon as it is diagnosed.*
> 2. *The earlier the reduction is carried out (in infants for the most part with minimal anesthesia), the shorter the required retention period (in infants only a few weeks), and the better the prognosis for a good result especially because of the potential for the better development of the head and the acetabulum. The late complications could be avoided.*[99]

For the retention of the hip in abduction, Hilgenreiner used a padded pasteboard splint (figure 3.53). He believed that every doctor should be able to establish the diagnosis in the newborn, but it was apparent that a long educational process was just beginning. Three years later, Nathaniel Allison of the Massachusetts General Hospital also emphasized early reduction.[100]

The most active advocate of early diagnosis and treatment of congenital dislocation of the hip was Vittorio Putti (1880–1940), the director of the Rizzoli Orthopedic Institute in Bologna. Putti made many contributions to the understanding of congenital dis-

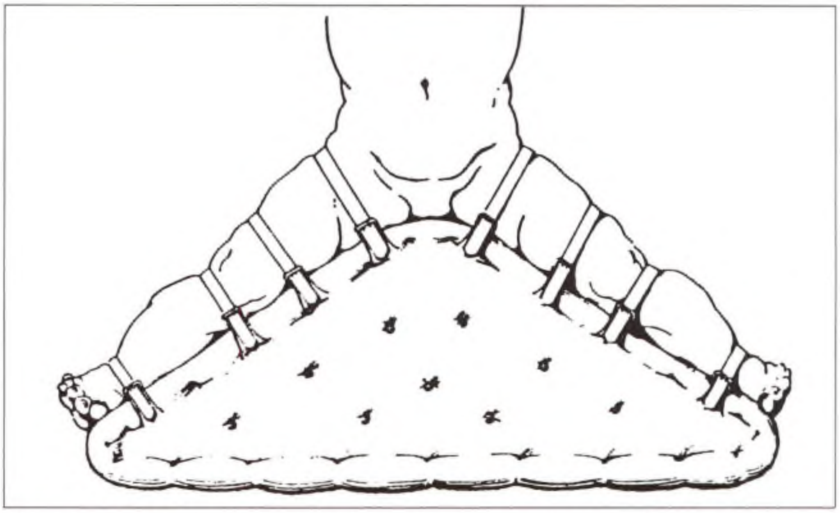


Figure 3.54 Putti's abduction pillow. From V. Putti, "Early Treatment of Congenital Dislocation of the Hip," *J Bone Joint Surg* 11(1929): 798–809.

Figure 3.55 Mario Ortolani (1904–1983). From Obituary: "Mario Ortolani," *Europ J Ped* 147(1988): 340.

location of the hip, not the least of which was the magnificent atlas of anatomical dissections of nine patients of all ages with the condition.[101] At a joint meeting of the British and American Orthopaedic Associations in London in July 1929, Putti spoke on this subject.

In conclusion, let me emphasize that to improve the results of the treatment of congenital dislocation, one must lower the age limit for beginning treatment. But to render this possible, it is necessary for parents to learn to bring their children for medical examination early, and that the doctors shall be able to make the diagnosis in time. That will certainly occur in the future with suitable propaganda and with better orthopaedic training for the medical profession. In Italy we have already felt the benefit in this direction of compulsory orthopaedic instruction in the universities.[102]

For the management of his patients, Putti used a cushion that held the legs in abduction (figure 3.54).

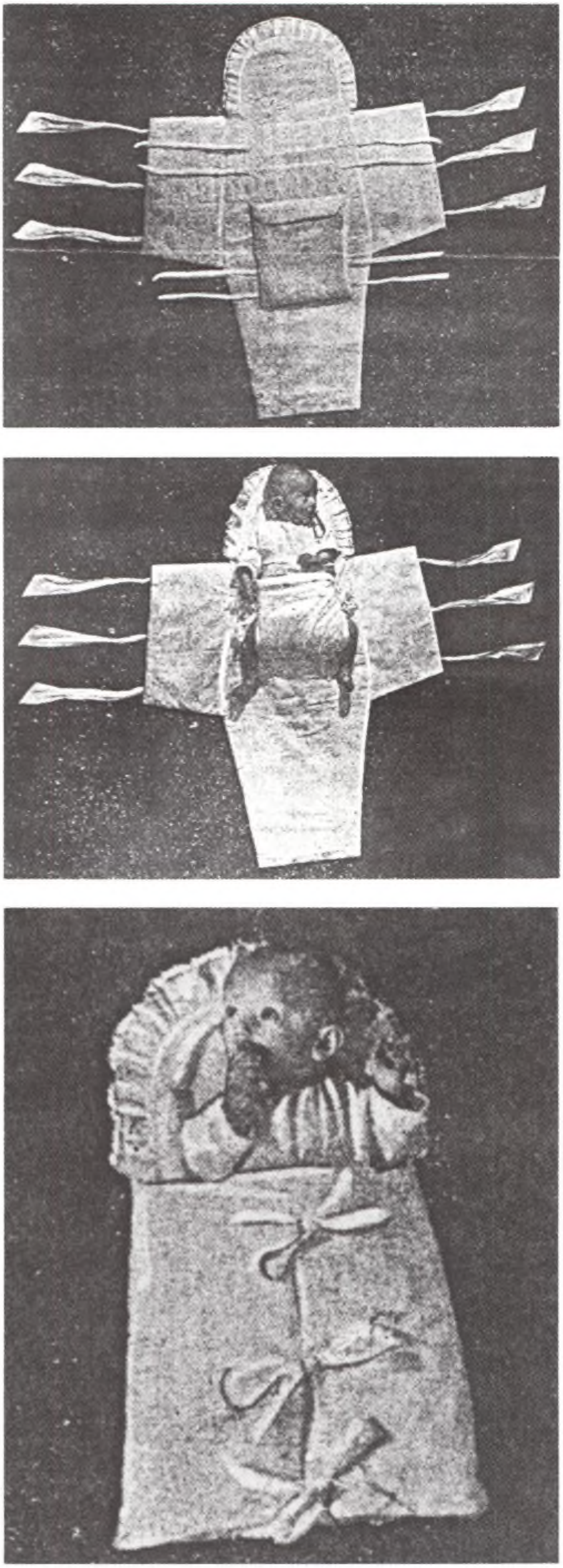
The early diagnosis and treatment of congenital dislocation of the hip recieved great impetus from the work of the Italian pediatrician Marino Ortolani (1904–1983)[103] (figure 3.55). A graduate of the University of Bologna, he began his career in a pediatric clinic in Ferrara. His major interest at that time was in *thalassemia major*, or Cooley's anemia, and it is of note that he instituted the first program of screening and genetic counseling for this condition. It was in the provincial institute for children in Ferrara in 1935 that Ortolani's attention was called by the mother of a five-month-old child to a "click" that she noted every time she washed and diapered the baby. Having reproduced the "click" himself, Ortolani obtained a radiograph of the pelvis, which demonstrated a congenital dislocation of the hip. Upon examining other patients in his clinic, he found a good correlation between the "click" and the presence of a dislocation. He described his findings in 1937 and *Ortolani's sign* became one of the most important clinical signs suggesting the presence of a congenital dislocation of the hip.[104] In 1946 the Italian government established the Center for the Diagnosis, Prophylaxis, and Treatment of Congenital Hip Dislocation, and Ortolani was made its director. Ortolani treated his young patients in abduction by using a pillow splint and obtained good results. Bedrich Frejka (1890–1972) modified the pillow splint of Ortolani and used it effectively[105] (figures 3.56–3.58).

Sophus von Rosen (b. 1898) in Sweden found that Ortolani's sign was reliable and he obtained good results by treating his patients in a padded aluminum splint.[106] He too emphasized the importance of early diagnosis: "Early diagnosis and early treatment presupposes cooperation between pediatricians in the maternity department, radiologists and orthopedic surgeons."[107]

T. G. Barlow in England arrived at a similar conclusion. He described a "reverse Ortolani's sign," a "click" produced when the head of the femur slipped out of the acetabulum over the posterior rim of the acetabulum.[108] He treated his patients with a simple abduction splint.

Arnold Pavlik (1902–1965) (figure 3.59) was not satisfied with the abduction splints that immobilized the hip. A strong advocate of continuous movement in the hip joint as a stimulus for normal development, he developed a harness that allowed hip motion in every direction except extension, while still retaining the elements of abduction[109] (figure 3.60). He believed that his system of functional treatment gave results superior to those obtained by passive immobilization. Pavlik was an assistant to Frejka in the clinic in Brno, where he had ample opportunity to observe the treatment of congenital dislocations of the hip. In 1939 he became chief of the clinic in Olmutz and later professor of orthopedics at the Palacky-University, which was established in Olmutz after World War II.[110]

It is important to remember that Lorenz talked of "so-called congenital dislocation of the hip" and that Hilgenreiner discussed subluxation and dysplasia of the hip.[111] It remained for Vernon L. Hart of Minneapolis to develop the concept of dysplasia-subluxation-dislocation as a continuous spectrum of abnormality.[112] The basis of all treatment for congenital dislocation of the hip, namely, placing the head in the developing acetabulum as early as possible to influence its development, was validated by the animal experiments of William S. Smith of Ann Arbor. He excised the head of the femur in puppies and found that the acetabuli failed to develop normally. He then placed metal cubes in the acetabuli of puppies. As these animals grew the acetabuli assumed the shape of the objects placed in them.[113]



Figures 3.56–3.58 The pillow splint of Bedrich Frejka. From Frejka, "Prävention der angeborenen Hüftgelenksluxation durch das Abductionpolster," *Wien med Wschr* 91(1941): 523–24.

Figure 3.59 Arnold Pavlik (1902–1962). From *Ortopediia Traumatologiia I Protezirovanie* 23(1962): 94.

Figure 3.60 The Pavlik Harness. From Peter Scoles, *Pediatric Orthopedics in Clinical Practice*, 2d ed. (Chicago: Year Book Medical Pub., Inc., 1982), 153.

Early treatment of congenital dislocation of the hip is the only means of obtaining good results with consistent regularity. All cases of congenital dislocation of the hip should be diagnosed and treated in early infancy, preferably during the first weeks of life.

When the diagnosis is made after the patient starts to walk, well directed conservative treatment offers satisfactory results in a large percentage of congenital dislocations of the hip. Open reductions are seldom necessary in children under three years of age.[114]

This statement by I. V. Ponseti of Iowa City, made in 1955, summarized what had been learned in the preceding 150 years. There is still much to be learned about congenital dislocation of the hip. This fact is made evident by the contents of the International Symposium in Memory of Marino Ortolani, held in Padua in October 1988.[115] There have been many congenital defects of the locomotor system that have captured the interest of orthopedic surgeons. None of them, however, occurred with the frequency of clubfeet and congenital dislocations of the hip, and none exerted greater influence on the development of orthopedic surgery as a specialty.

Notes

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CHAPTER FOUR

Deficiency Diseases

IT WAS NOT UNTIL the second quarter of the twentieth century that the twin scourges of scurvy and rickets came under control. Both of these conditions occurred in infants and children, and at first they were difficult to separate. Rickets was first described by Daniel Whistler (1619–1684) in 1645.[1] However, credit for bringing the disease to the attention of the medical world has generally been attributed to Francis Glisson, whose book, published in 1650, gave a more complete description of rickets and also included the first account of infantile scurvy.[2]

Francis Glisson (1597–1677) (figure 4.1) was born in Dorsetshire and attended both Cambridge and Oxford Universities before receiving his medical degree in 1634.[3] The following year he became a member of the Royal College of Physicians and was made Regius Professor of Physic at Cambridge, a position he held until his death. Glisson played an important role in the medical and scientific affairs of his time. He was one of the founders and first members of the Royal Society. He was particularly famous as an anatomist and is remembered for his description of what came to be known as *Glisson's capsule*, which is the membrane surrounding the liver. In the preface to his book on rickets, Glisson and two of his colleagues point out that the material in the book was collected by a committee consisting of Glisson and seven collaborators, making this gathering one of the earliest instances of collaborative research carried out in England. The condition that he described was called *rickets* by the local population, and while Glisson labored to find its root in Greek, it probably stemmed from the Anglo-Saxon or Old English *wrick* or *wrikken*, that is, to twist, or to *wrick*, one's ankle.[4] Because the disease was originally described

Figure 4.1 Francis Glisson (1597–1677). From John Ruhräh, *Pediatrics of the Past* (New York: Paul B. Hoeber, Inc., 1925), facing p. 257.

in England, it became known as the English disease (*morbus anglicus, morbus angloram*), as well as rachitis and rickets.

Glisson based his work concerning rickets on observations made at the autopsy table. He noted the large head, the atrophy of the muscles of the extremities, and the prominent abdomen.

About the joynts, especially in the wrists and ankles certain swellings are conspicuous, which if they are opened, not in the fleshy or membranous parts, but in the very ends of the bones, you may perceieve them to be rooted in their appendances; and if you will file away those prominencies of the bones, you will easily perceive them to be of the same similarly substance with the other parts of the bones. . . . The top of the ribs to which the stern is conjoyned with gristles, are knotty, like unto the joynts of the Wrists and Ankles, as we have already said [the rickety rosary].

Moreover, To this Article we opportunely add the inflexion of some of the Joynts, as of the Knees and Ankles, which happeneth very frequently in this Disease, sometimes being made inwardly, sometimes outwardly. And this bending also seemeth to be not unfitly referred to the inequality of nutrition. For if it happen by unequal nutrition, that one side of the Shank-bone be so lengthened more then the other: suppose outwardly, that it doth somewhat lift up the outward part of the Epiphysis of the Shank-bone above the inward part, the joynt in the Knee must needs stand outwardly bent; and on the contrary, if the inward part be lifted up, and the outward depressed, the same Joynt must needs stand inwardly bent.

Fourthly, Some Bones wax crooked, especially the Bones called the Shank-bone, and the Fibula or the small Bone in the Leg, then afterwards the greater Shank-bone, and the undermost and lesser of the two long Bones of the Elbow, but not so much altogether nor so often; sometimes also the Thigh-bone and the Shoulder-bone. Again, there is sometimes observed a certain shortening of the Bones and defective growth of them in respect of their longitude [5] [figures 4.2–4.3].

Glisson also noted correctly that the disease did not occur in children younger than six months old, and occurred most frequently in children of the well-to-do rather than in those of the poorer classes. He also noted that scurvy was sometimes seen in patients with rickets. He described the use of swathing and splints for the extremities and the use of suspension and local pressure to prevent the progress of spinal deformities.

In 1669, John Mayow (1643–1679) of London published a small monograph entitled *De Rachitide*, which presented the subject of rickets more concisely than did the work of Glisson, but provided no additional useful suggestons for treatment.[6] In a short section from his work *Orthopaedia* entitled "The Body Deformed by Rickets," Nicholas Andry enlarged on the value of exercises and suspension, but like those before him offered no

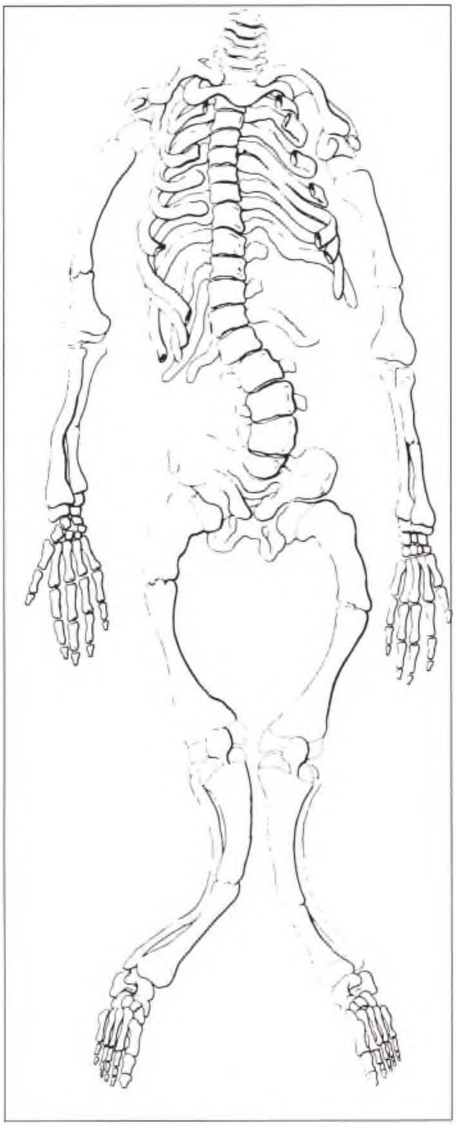


Figure 4.2 A rickety skeleton. From J. M. Delpech, *De l'Orthomorphie* (Paris: Gabon, 1828), atlas plate 32.

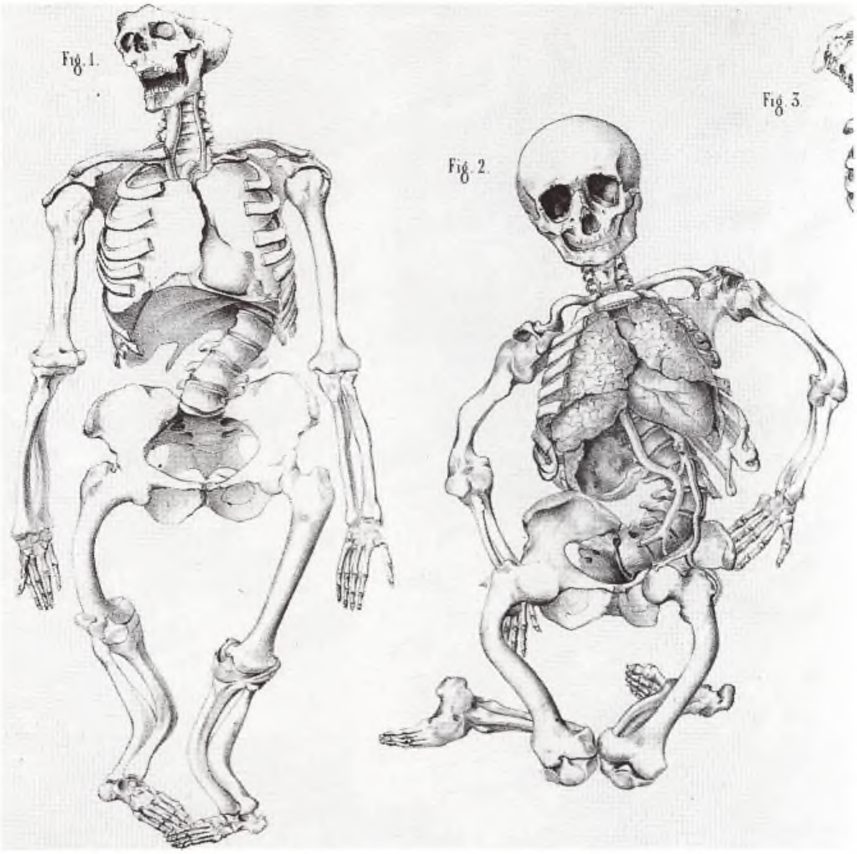


Figure 4.3 Deformities caused by severe rickets. From H. Bouvier, *Leçons cliniques sur les maladies chroniques de l'appareil locomoteur* (Paris: J. B. Baillière et Fils, 1858), atlas pl. 6.

effective medical treatment.[7] He believed that many of those patients discussed in the section "The Legs Crooked," whom he treated with splinting, had rickets.[8]

In spite of the fact that Glisson and his contemporaries thought of rickets as a new disease, there is little question that it had occurred to some extent in some societies for centuries.[9] In an interesting analysis of Renaissance paintings of the Holy Family, Foote has pointed out that the depictions of the infant Jesus often give him the stigmata of rickets, namely, the large head, the protuberant abdomen and the atrophic extremities.[10] This might indicate that these characteristics were so common that they were thought to be the norm.

It was not until the works of Julius O. Möller and Thomas Barlow that a clear distinction between rickets and infantile scurvy was made clinically. Julius O. Möller (1819–1887) was born and educated in Königsberg, East Prussia, where he also practiced medicine. In 1859 he published a paper dealing with what he called *acute rickets*, which described infantile scurvy.[11] This paper preceded the publication of Thomas Barlow's paper, "On Cases Described as 'Acute Rickets'," which appeared twenty-four years later.[12] These two papers are the basis for referring to infantile scurvy as Möller-Barlow's disease.

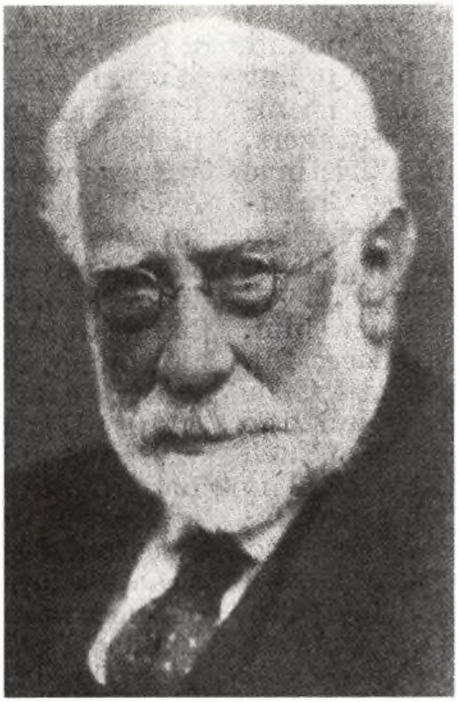


Figure 4.4 Thomas Barlow (1845–1945). From Obituary: "Thomas Barlow," *Lancet* 1(1945): 131.

Thomas Barlow (1845–1945) (figure 4.4) was born in Lancastershire and, after a preliminary education in Manchester, studied medicine at University College in London.[13] He became a physician on the staff of Charing Cross Hospital and the Hospital for Sick Children, Great Ormond Street. He was the physician to Queen Victoria during her last illness and was also physician to Kings Edward VII and George V. He was president of the Royal College of Physicians from 1910 though 1914. His longevity was rewarded by the opportunity to see the causes of rickets and scurvy discovered, two diseases in which he had a special interest, and to see effective prophylaxis and treatment become available.

Barlow's description from his paper on acute rickets is a fine example of clinical medicine as practiced before the development of the clinical laboratory and the X-ray.

A boy, aged fifteen months, was seen in the month of December when the following note describes his condition: The child has an excessively pale, sallow complexion and is flabby, although he has a moderate covering of fat. There is no sign of nervous disease or of visceral disease except that the liver is perhaps larger than normal, extending to two fingers' breadth below the thoracic margin as the body lies in the horizontal posture. The bowels have acted once or twice daily; a stool which has been saved is greyish-brown in colour and a little slimy. There has been no vomiting; the tongue is clear. He has cut his two lower incisors; the gums are natural with the exception of a minute erosion in the upper gum opposite the cutting edge of one of the lower teeth. The boy is continually moaning and when approached he screams and still more when he is touched. It is difficult to describe the cry, but it is sufficient to say that in this case it suggested deep-seated pain connected with bones and not brain disease. And it is clear that the dominant symptoms are related to the bones. The boy is rickety; there is some beading of ribs although the thorax is not grooved, his epiphyses are a little enlarged and he has only two teeth, but rickets is not sufficient alone to explain his condition. He lies on his back and scarsely moves the trunk though he frequently turns his head from side to side. Both radii are enlarged at the lower end but the right more so than the left, not only in circumference but in vertical measurement to a slight amount. It, in fact, suggests a rickety enlargement plus slight thickening extending upwards for perhaps an inch. The child cries wherever he is touched, but the mother has noticed his right wrist notably more tender than the other for a day or two. The skin is pale in the neighbourhood and there is no special heat to be felt. The upper limbs are not bent. The left thigh is kept half flexed. Both the left thigh and leg are slightly swollen so that the contour of the limb is different from natural, assuming in the thigh rather a cylindrical shape. It is of the same colour as the other limb and does not feel hotter than any other part of the body. There is no fluctuation and no sign of effu-

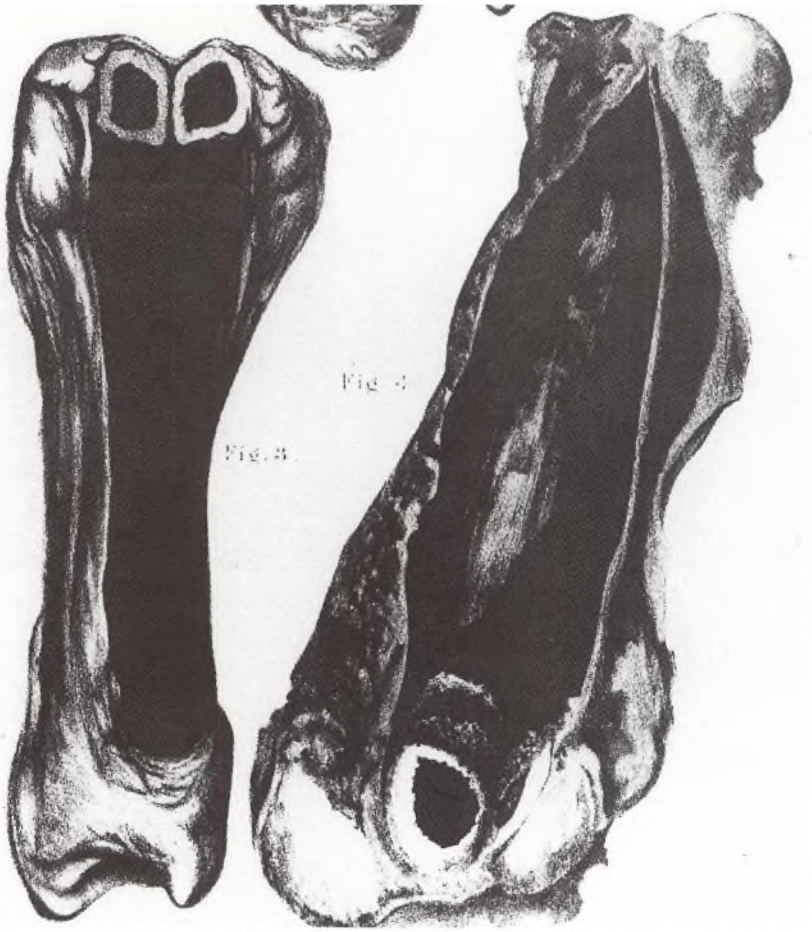


Figure 4.5 Subperiosteal hemorrhages in the tibia and femur due to scurvy. From Thomas Barlow, "On Cases Described as 'Acute Rickets'," *Med Surg Trans* 6(1883): 159–219, pl. 7, figs. 3–4.

sion in the knee or ankle joint. The child screams so much that one cannot examine thoroughly, but in spite of his thigh being flexed there does not seem reason to suspect hip-joint trouble.

The epiphyses of at the knee and ankle are enlarged.

The right thigh is natural in the sense of there being no swelling. Besides the slight enlargement of epiphyses at the knee there is a tendency to knock-knee on the right side. There is no general swelling of the right leg but there is a little thickening to be appreciated down the shaft of the right tibia. . . .

As to diagnosis, it was obvious that the child was the subject of rickets to a moderate degree, and equally obvious that rickets alone was insufficient to explain all his symptoms.

On the ground of certain post mortems which are subsequently detailed, the opinion was formed that in this case there was under the periosteum of the left femur and tibia an effusion of blood, and that the extreme tenseness of the limb was due to blood extravasation in the deeper muscular layers with the serum filtered out into the more superficial parts [figure 4.5].

It seemed likely that there was also some slight blood effusion immediately around the shaft of the right tibia and also in the neighbourhood of the junction of the shaft and lower epiphysis of the right radius. The view held was that the boy was suffering from the supervention of scurvy on rickets, albeit there was no trace of sponginess of gums. The treatment suggested was to surround the whole of the left lower limb and the right leg with wet compresses which had been thoroughly wrung out. These were to be surrounded with dry clothes rather closely applied, and the compresses were to be changed every two hours. A complete change was made in the diet. He was ordered daily the juice of a quarter pound of raw beef sweetened a little. He was also to take a pint and a half of cow's milk daily, to which was to be added in his alternate meals at one time a third of strained gruel and at another a third part of barley water, and finally two teaspoonfuls of orange juice were to be given daily. . . .

After this the improvement was progressive.[14]

Following the descriptions by Möller and Barlow, the disease previously called acute rickets was recognized for what it really was, infantile scurvy. Scurvy in adults was a well-known disease. The value of orange juice and other citrus juices in its prevention and treatment had been well established by the British navy.[15] The application of this knowledge to the treatment of infantile scurvy was simple and effective.

The American Pediatric Society became very interested in infantile scurvy and in 1898 published a survey of its members on the subject.[16] The report was based on a review of 379 cases reported by 138 observers. It clarified the symptomatology and clinical findings in infantile scurvy and emphasized that it was a frequent and serious disease in pediatric practice.

During the first quarter of the twentieth century there were many investigations of essential nutritional factors. One of these, carried out by J. Axel Hojer in Sweden, thoroughly discussed the effects of scurvy on bone growth and other organ systems.[17] In the introduction to this work, published in 1924, Hojer states:

After the strenuous research during the last twenty years of a number of distinguished investigators, it has now been proved that scurvy has to be looked upon as one disease in adults, young children and infants, in monkeys and guinea-pigs, with the same etiology, the same unknown pathogenesis, similar clinical symptoms and pathoanatomical changes, and identical therapeutics. Scurvy, however, is above all a disease of growth, and the most profitable studies have been made in quickly growing organisms, human infants or young monkeys and guinea-pigs. As surely as the quicker growth is a fundamental physiological factor, which principally distinguishes the undeveloped organism of the child from the developed organism of the adult and constitutes pediatrics as a special branch of medical science, as surely the scurvy problem is a central pediatric problem.[18]

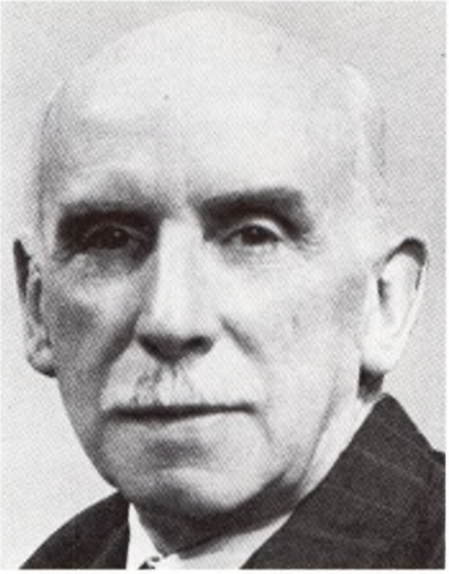


Figure 4.6 Leonard Gregory Parsons (1879–1950). From A. V. Neale, "Sir Leonard Gregory Parsons," *J Ped* 48(1956): 530.

The most pronounced difference between scurvy and rickets in the bone-system is their relation to the calcification. In rickets, an osteoid substance is formed which is not calcified. In scurvy, a bone is formed to a limited extent, which is rapidly calcified.[19]

Of particular interest was the relationship between tuberculosis and scurvy, a subject to which Hojer paid special attention. He observed that resistance to tuberculosis was lessened during an episode of scurvy, and concluded, on the basis of experiments with guinea pigs, that this was due to the failure in the scorbutic animal of normal connective tissue to react to the tuberculous focus.[20]

Continued research resulted in the discovery of ascorbic acid, or Vitamin C, by Albert Szent-Gyorgyi in 1928.[21] In 1933 Leonard G. Parsons (1879–1950) (figure 4.6) reported the first case of infantile scurvy in which crystaline ascorbic acid, obtained from Szent-Gyorgyi, had been used successfully to cure the condition.[22] Parsons was one of the founders of the specialty of pediatrics in Great Britain and he developed the Birmingham Children's Hospital into a major pediatric center. His interests were primarily in nutrition and the effects of malnutrition.[23] As a result of the widespread use of citrus juices and ascorbic acid in the diets of infants and small children, infantile scurvy has become a very rare condition.

While the treatment of patients with scurvy was not ordinarily a concern of surgeons except for the problem of differential diagnosis between scurvy, acute hematogenous osteomyelitis, pyogenic arthritis, and trauma, patients with deformities caused by rickets were another matter. Most of the orthopedic literature dealing with the subject has tended to follow the example of Nicolas Andry, who discussed rickets in one section of his book *Orthopaedia,* and the treatment of deformities of the extremities, almost all of which were caused by rickets, in another section.[24] While he had nothing important to offer in the section on rickets, it was in the section on treatment of deformities in the leg that he discussed the value of splinting, using the famous crooked tree as an example. He also inveighed against early weight bearing in small children if there was a tendency to deformity. For the next two hundred years there was little change in this approach to management in early cases, except for the increasing complexity of the braces employed (figure 4.7).

Osteoclasis, or the intentional fracture of a bone in order to correct a deformity, could be carried out manually or by means of instruments called *osteoclasts* (figures 4.8–4.9). The manual method had its advocates, but was not popular. A. H. Tubby criticized the method because the fractures produced could be oblique, comminuted, or in the wrong place and the collateral ligaments of the knee or the epiphyses could be damaged.[25] An osteoclast of his own design was used by Francesco Rizzoli

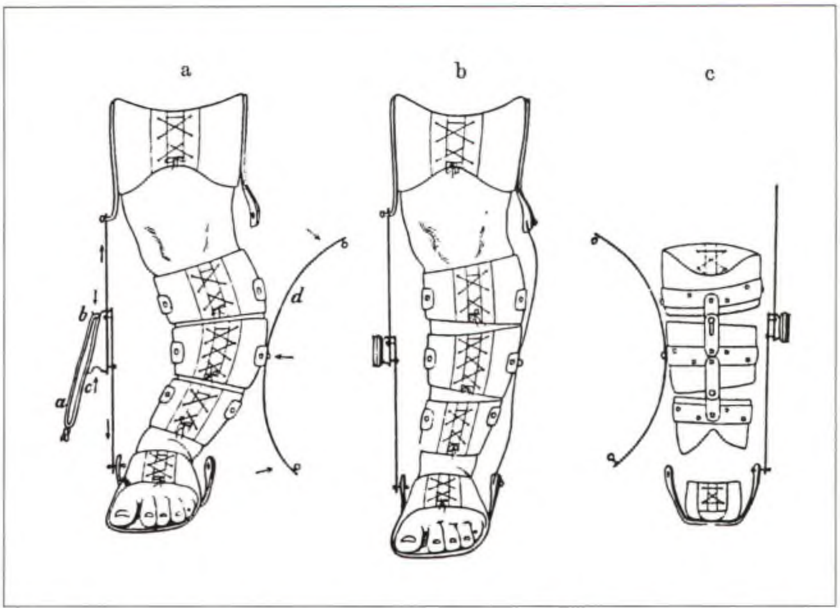
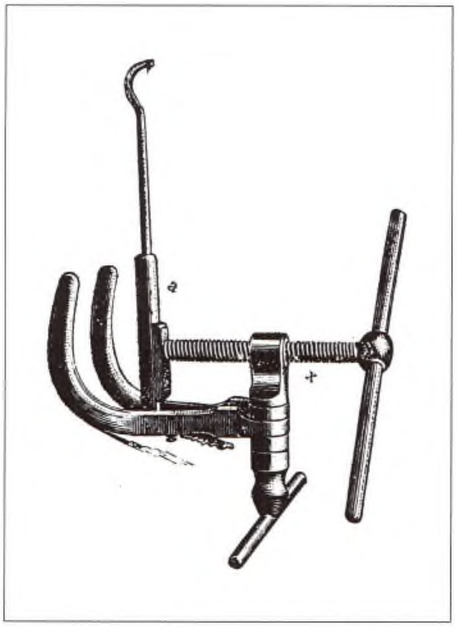
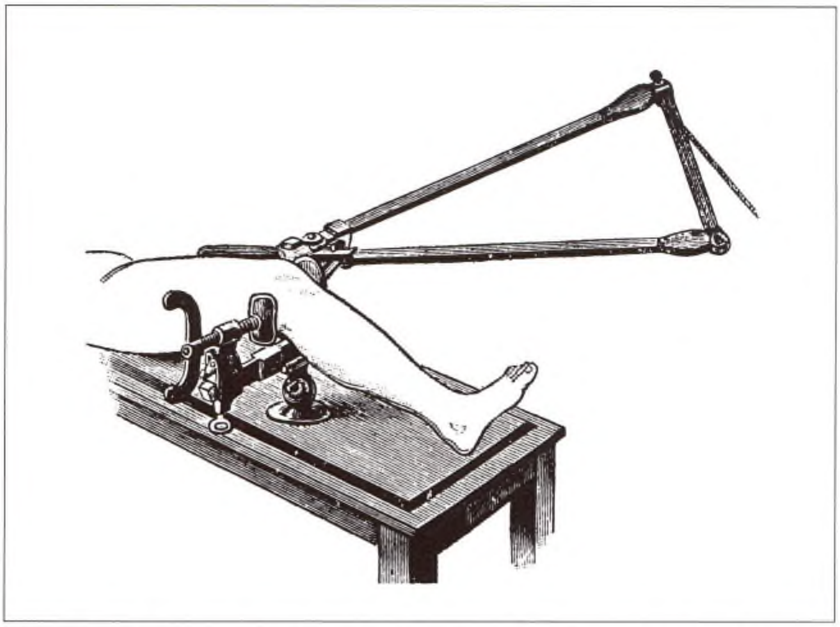


Figure 4.7 An example of a complicated leg brace. Hoffmann's apparatus for correcting the deformity in a rachetic tibia. This active splint utilized both elastic bands and springs. From *Handbuch der orthopaedischen Chirurgie*, ed. Georg Joachimsthal (Jena: Gustav Fischer, 1905–1907), 2:569.

(1809–1880) of Bologna in 1869 as a method of equalizing leg length.[26] Even with an osteoclast, it was difficult to fracture the diaphysis of the bone close to the joint. However, osteoclasts remained in the armamentarium of orthopedic surgeons well into the first quarter of the twentieth century.

John Rhea Barton (1794–1871) of Philadelphia is credited with being the first to perform a surgical division of a bone, that is, an osteotomy, for the correction of deformity. In 1826 Barton divided the femur at the level of the lesser trochanter with a small saw through a short lateral incision and, as he intended, produced a pseudoarthrosis.[27] Eleven years later he carried out a corrective osteotomy on the distal femur of a physician with an ankylosis of the knee in marked flexion.[28] The deformity, the result of a septic arthritis occurring many years previously, was totally disabling. Barton exposed the supracondylar portion of the femur by an anterior incision and removed a wedge of bone with a saw, leaving the posterior cortex as a hinge. The wound was allowed to heal by secondary intention and during the healing process the limb was gradually straightened (figure 4.10). When bony union had matured, the limb was eminently functional. Almost forty years later Samuel D. Gross (1805–1884) reported that he had followed the results of fourteen such operations and found that twelve patients had recovered and two had died of infection.[29]

Because of the high risk of infection and its complications, other surgeons developed methods similar to the subcutaneous osteotomy (a very small incision through which a very narrow

Figures 4.8–4.9 Left to right: Grattan's osteoclast and Colin's osteoclast. From A. H. Tubby, *Deformities Including Diseases of the Bones and Joints* (London: Macmillan & Co., Ltd., 1912), 1:648.

instrument was inserted) in the hopes of alleviating the risk of infection. Bernhard Langenbeck (1810–1887) in Berlin used a saw with a point an eighth-of-an-inch wide and four inches long, which was introduced through a very small incision to divide the femur almost completely, the remainder of the femur being fractured as the deformity was corrected. In 1854 he reported three cases in which he had used this technique.[30] Many other surgeons devised instruments and carried out subcutaneous osteotomies, but all were dogged by high rates of infection. Until the introduction of antiseptic and aseptic surgical techniques, the risk of such operations was substantial.

In 1875 Richard Volkmann (1830–1889) of Halle, a close friend and admirer of Joseph Lister (1827–1912), described two cases of osteotomy carried out using the antiseptic system.[31] The two patients, both girls aged thirteen, had had longstanding tuberculosis of the knee, which had fused in severe flexion. In one girl, osteotomy of the distal femur alone sufficed to obtain correction of the deformity; in the other, osteotomy of the distal femur and proximal tibia were necessary. In both cases the wounds healed without infection. Immediately following this, William Macewen (1848–1924) (figure 4.11) in Glasgow began his work on osteotomy, which was summarized in his book *Osteotomy with An Inquiry into the Aetiology and Pathology of Knock-knee, Bow-Leg and Other Osseous Deformities of the Lower Limbs*, published in 1880.[32]

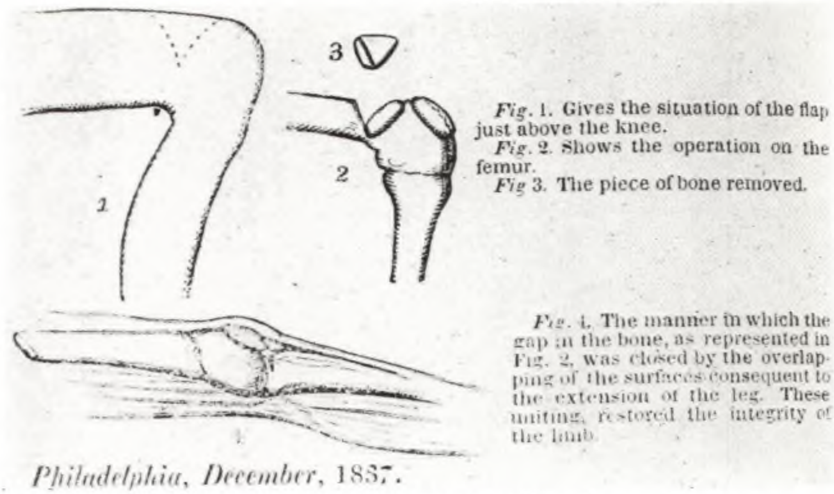


Figure 4.10 The osteotomy performed by John Rhea Barton to correct a severe flexion deformity of the knee. From Barton, "A New Treatment in a Case of Anchylosis," *Am J Med Sci* 21(1837): 332.

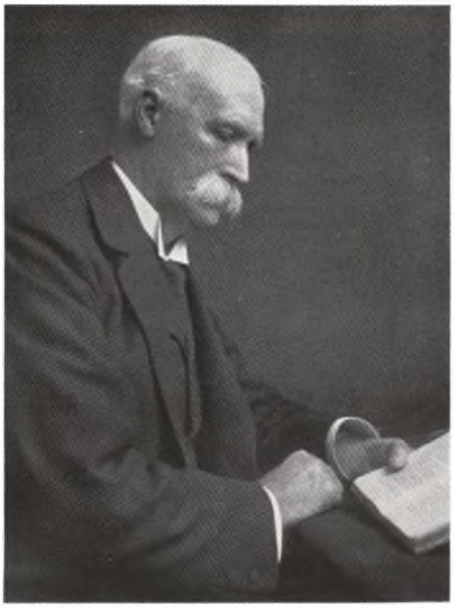


Figure 4.11 William Macewen (1848–1924). From A. K. Bowman, *The Life and Teaching of Sir William Macewen* (London: William Hodge and Co., Ltd., 1942), frontispiece.

William Macewen was born on the island of Bute off the west coast of Scotland, where his father ran a small shipping business.[33] When he was twelve years old his father retired and moved his family to Glasgow, where William continued his education. As a medical student on the wards of the Royal Infirmary, he came under the spell of Joseph Lister. As his surgical training progressed, Macewen became a firm believer in Lister's ideas regarding the antiseptic treatment of wounds. After graduating in 1869, he continued his surgical training at the Royal Infirmary and joined the hospital staff as a surgeon following experience as a general practictioner. He had a long and illustrious career. His contributions to chest surgery and neurosurgery were very important, and his studies of bone growth, bone grafting, and osteotomy were major contributions to orthopedic surgery.[34]

Macewen's views were far in advance of his time. Reflecting on conditions in Glasgow while speaking about tuberculosis, he said:

In the old days the light that entered our houses was taxed and the windows became smaller; today, the powers that be tax the air contained therein, and for every cubic foot of air enclosed additional charge is made. In order to escape or to lessen this burdensome assessment, many huddle themselves and their families into dwellings of the smallest compass, where they inhale pre-breathed air, with the resultant lowering of vitality, germ dissemination, disease and death. Then we appoint commissions to find out the cause of the deterioration of the race!

Every man who is born has an inalienable right to as much fresh air as he is able to consume; but the powers that be say: "God may give you the right, but we shall tax you for using it." It is true that they do not as yet tax us for the amount of air we inhale out of *doors, possibly because they do not know how to estimate the individual consumption. Yet the governing bodies are full of humanity and have the best intentions. When the ravages of tuberculosis can no longer be hidden, as the disease stares them in the face, they are moved to grasp at the first thing that appeals to them, and they say to the afflicted "Come, let us help you; we shall put you in sanatoria." What happens there? The patient has his birthright restored to him in being able to breathe the fresh air which God has meted out so freely, and for the use of which he was previously taxed.*[35]

Writing in a similar vein about rickets he said:

Children reared in some parts of a city like Glasgow, confined to close houses or compelled to play in crowded streets, breathing, for the greater part of the year, air more or less filled with carbon and contaminated by the effluvia from sewers and emanations from chemical works; shut out from the light partly by the height of the houses, partly from the fact that even the sun's rays which do manage to struggle through the canopy of smoke which envelopes them, are so diluted that they are of comparatively little value; such children can scarcely be expected to be anything but feeble and liable to succumb to epidemics or to have severe sequelae, leaving permanent effects.

That bad air is even more potent than scant food, may be adduced from the fact that there are many people living in the West Highlands of Scotland on very poor diet, poorer than what most of the poor classes in our towns have, and yet there seems to be little rickets among them. Although from most quarters in Scotland cases of distorted limbs have presented themselves for treatment, there has not been one from the West Highlands. The fresh air and the sea breezes appear to compensate for the lack of sufficient food.[36]

Macewen was very close to the mark. It is only very recently that incidence of rickets has been related to the introduction of soft coal and the industrial revolution. W. F. Loomis in discussing this concept concluded that "although it is still regarded as a dietary-deficiency disease resulting from a lack of Vitamin D, it results from a lack of sunlight. In smokey cities it was the first air-pollution disease."[37]

Prior to Macewen, surgeons divided the bone with chisels and saws. He discarded the saw as inappropriate for the task and used the chisel only for paring, shaving, or cutting wedges out of the bone. For dividing or making incisions into the bone he designed a new instrument that he called an *osteotome*. The osteotome was quite similar to a chisel except that at the cutting edge it was beveled on both sides to resemble a very slender wedge. His osteotomes were made with a calibration in inches marked on the shaft so that it could be determined how far the instrument had been advanced through the skin. He was very particular about the material and temper of his chisels and osteotomes and how they were to be used.

> *It is advisable that one wishing to use them should practice on the dead subject, or on the bones of animals, so as to familiarize the hand and acquire the necessary dexterity. A carpenter would not permit a fine piece of work to pass into the hands of one not thoroughly conversant with the use of his tools; how much more is it necessary that the surgeon should know the manner of handling his instruments and be cognizant of the principles on which they work.*[38]

The osteotome became the classic instrument for use in bone surgery and still maintains a prominent place in the orthopedic armamentarium.

The operation of subcutaneous osteotomy was performed with the limb supported on a sand bag (figure 4.12). Operations were carried out under anesthesia and a tourniquet was used. The incision was made parallel to the muscle fibers and the osteotome inserted down to the bone. It was then turned one hundred eighty degrees and the bone divided (figure 4.13). The deformity was corrected and the leg was placed in a splint. In the five years between the first performance of the operation and the publication of his book, Macewen operated upon 557 limbs in 330 patients, with generally satisfactory results (figures 4.14–4.15).

The debate between those who favored an early surgical correction of the deformity and those who advised continuing conservative treatment with splints is well summarized by Joel Goldthwaite in a report of the experience at the Boston Childrens's Hospital with osteotomy and osteoclasis.[39] He reported good long-term results in cases treated early (average four years old) by osteotomy or osteoclasis. His results, reported in 1889, are illustrated by tracings made of the legs before and after treatment. Roentgen's discovery of of X-rays in 1896 allowed a greater accuracy in diagnosis, a more accurate determination of the level of the osteotomy, and a permanent record of the progress of healing and deformity. Surgeons quickly took advantage of the new discovery. Charles A. Morton in Bristol published a skiagraph, the earlier version of an X-ray, of a case of knock-knee due to rickets in 1897, followed four years later by a more extensive report on osteotomy for knock-knee accompanied with X-rays.[40]

The routine use of X-rays, and particularly the use of intraoperative X-rays, continued to improve the results of the correction of deformities by means of osteotomies. While not needed as frequently for the treatment of rachitic deformities, osteotomies continue to be used to correct a wide variety of other deformities.

Of all the many folk remedies used for the treatment of rickets, one became recognized as being of real benefit and was adopted by regular medical practitioners. Cod-liver oil was widely used as a

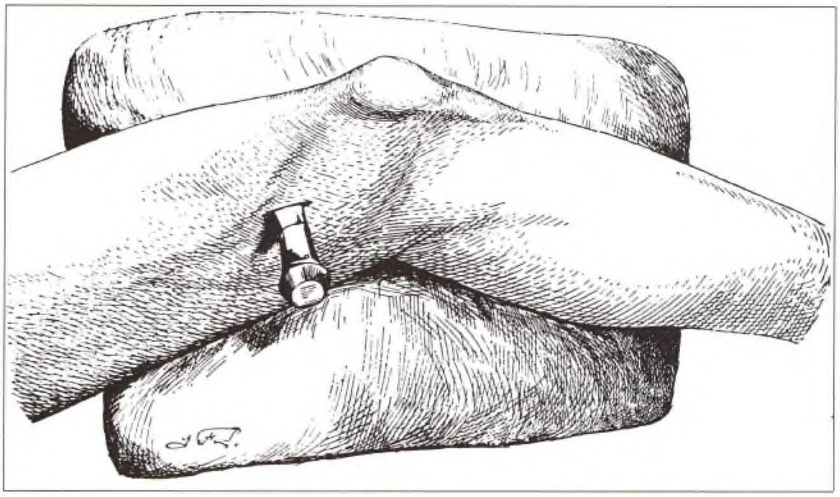


Figure 4.12 The positioning of the limb on the sand bag in preparation for osteotomy. From F. Calot, *Indispensable Orthopaedics*, trans. A. H. Robinson and Louis Nicolle (London: Bailliere, Tyndall & Cox, 1914), 621.

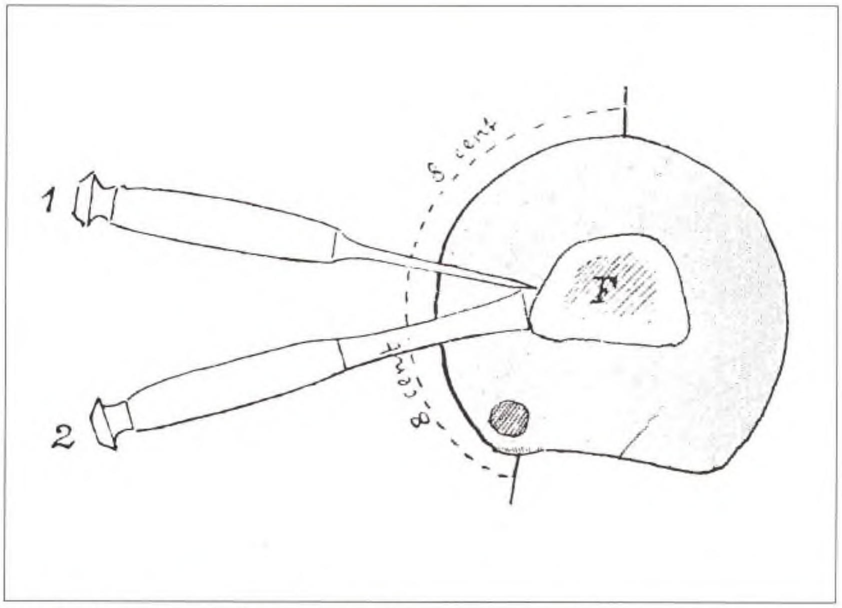


Figure 4.13 The method of using the osteotome for subcutaneous osteotomy: (1) The blade inserted down to the bone parallel to the muscle fibers; (2) The blade turned ninety degrees to transversely divide the bone. From Calot, *Indispensable Orthopaedics*, 619.

Figures 4.14–4.15 Three children with deformities due to rickets, and the same children following recovery from corrective osteotomy. From Calot, ***Indispensable Orthopaedics***, 614–15.

remedy by people living in northern Europe.[41] During the nineteenth century, it slowly entered the list of remedies prescribed by physicians, and by the end of the century the use of cod-liver oil for the treatment of rickets was firmly established in pediatric practice. In 1922 E. V. McCollum and his associates at Johns Hopkins University were studying rickets in experimental animals and demonstrated the existence of a substance contained in fats, which was different from Vitamin A, and which they believed to be a vitamin whose specific property was to regulate the metabolism of bones.[42] This substance became known as Vitamin D. The magnificent metabolic balance studies carried out by Fuller Albright and Edward Reifenstein defined its effects on the bone and on the kidneys.[43] Shortly after this it was recognized that there were forms of rickets that did not respond to treatment with the usual therapeutic doses of Vitamin D, so-called resistant or refractory rickets.[44] The biochemistry of the substances grouped under the heading of Vitamin D and their relationship to rickets has proved to be very complicated and is still under continuing investigation.

As Loomis pointed out in 1970, it is now believed that rickets results from lack of exposure to sunlight, and should not be regarded as a disease of dietary deficiency.[45] In 1955 L. Emmett Holt, the distinguished pediatrician, spoke of his experience with rickets in the early 1920s.

> *The diseases from which our patients suffered differed considerably from those we see today. Fully half of the babies admitted to the hospital had clinical evidence of rickets, and the remaining, if they came to autopsy, showed evidence of the disease almost invariably. There was no accepted treatment of rickets or for the tetany which so often accompanied it. Cod liver oil was sometimes given, in small doses, without great faith in its efficacy, and the tetanies went on having convulsions for days and often weeks.*

The conquest of rickets was certainly one of the most notable achievements of the early years after World War I.

The disappearance of rickets from the pediatric clinic began in the mid twenties as routine prophylaxis was introduced, and, like most other innovations, required a decade or more to be generally accepted. But by 1940, rickets due to Vitamin D deficiency was a matter of history.[46]

Unfortunately, Holt may have been too optimistic, for Francis H. Glorieux, in his preface to a symposium on rickets published in 1991, made this comment: "The term rickets may sound like a headline in the history of medicine but, in fact, it is very much a current problem for todays physicians."[47]

There is a good understanding of the role vitamins, minerals, and other essential elements play in the growth and development of healthy children. When all of these factors are present in adequate amounts and at the right time, normal growth potentials can be achieved regularly. When these factors are missing or present but in inadequate amounts, or when malnutrition occurs as a result of want or of ignorance, children will pay the penalty.

Notes

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2. Francis Glisson, *De rachitide sive morbo puerili, qui vulgo The Rickets dicitur* (London: G. Du-gardi, 1650).

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4. Ibid., 262.

5. Ibid., 262–63, 268, 275–76.

6. Ibid., 341–48.

7. Nicolas Andry, *Orthopaedia: Or, the Art of Correcting and Preventing Deformities in Children* (London: A. Millar, 1743), 127–30.

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13. Obituary: "Thomas Barlow," *Lancet* 1(1945): 131–32.

14. Barlow, "On Cases Described as 'Acute Rickets'," 161–63.

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17. J. Axel Hojer, "Studies in Scurvy," *Acta paed* Supp. 3(1924): 1–278.

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20. Ibid., 140–71.

21. Albert Szent-Gyorgyi, "Observations on the Function of Peroxidase Systems and the Chemistry of the Adrenal Cortex: Description of a New Carbohydrate Derivative," *Biochem J* 22(1928): 1387–1409.

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24. Andry, *Orthopaedia*, 127–30, 210–12.

25. A. H. Tubby, *Deformities Including Diseases of the Bones and Joints* (London: Macmillan and Co., Ltd, 1912), 1:647.

26. Franz Rizzoli, "Das Übereinanderschieben der Fragmente einer zufallig Fractur des Femur zur Behebung des Hiken, welches durch unverbesserliche Verkurzung des entgegengesetzen Beines bedingt wird," *Wien med Wschr* 19(1869): 1238–40. *See also* chapter 7.

27. John Rhea Barton, "On the Treatment of Anchylosis by the Formation of Artifical Joints," *N Am Med Surg J* 3(1827): 279–92.

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36. Macewen, *Osteotomy*, 14–15.

37. W. F. Loomis, "Rickets," *Sci Am* 223(1970): 77–91.

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CHAPTER FIVE

Osteomyelitis

A BACTERIAL INFECTION that involves the bone and bone marrow is called *osteomyelitis.* One of the common results of such an infection is the death or *necrosis* of portions of the bone. Before the nature of the infectious processes was understood completely, osteomyelitis was sometimes simply called necrosis. This terminology persists today only in reference to the process in which the death of portions of bone occurs in the absence of infection, that is, *aseptic necrosis.*

Infections arise in bone as a result of direct inoculation of organisms through open wounds or open fractures, or as a result of organisms lodging in the blood vessels of the bone that are then disseminated throughout the bloodstream from a primary focus of infection in the soft tissues. These processes have been going on for millions of years, a fact that is shown by the discovery of characteristic changes in fossil bones.[1] At their inception, these two mechanisms of infection can be separated by the mode of onset in two ways. In one case there is a history of the direct introduction of contamination of the bone through a wound; in the other, the infection of the bone occurs through bacteria carried to the bone in the bloodstream and there is no local point of entry of infection. In the chronic or late stage of bone infections, the pathologic process in the bone is essentially the same regardless of etiology and involves sequestration and involucrum formation.

A sequestrum is a piece of dead or necrotic bone, devoid of circulation, that has become separated from neighboring, live, healthy tissue. An involucrum is a sheath of healthy new bone surrounding the sequestrum that arises from the periosteum in

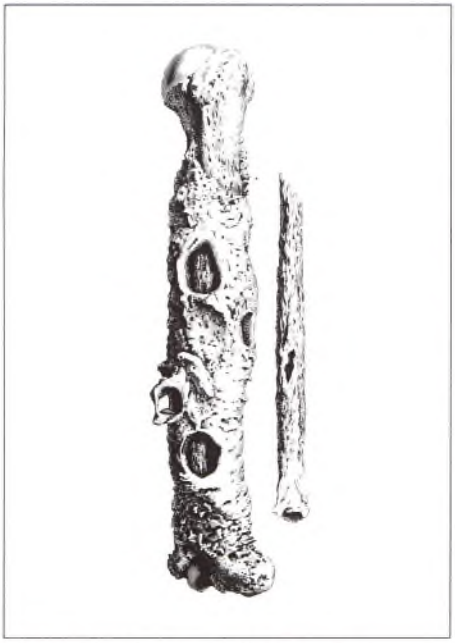

Figure 5.1 A chronically infected humerus resulting from a gunshot wound, with an involucrum surrounding a sequestrum that consists of a major portion of the original humerus. From William Cheselden, *Osteographia, or the Anatomy of the Bones* (London, 1733), pl. 60, fig. 1.

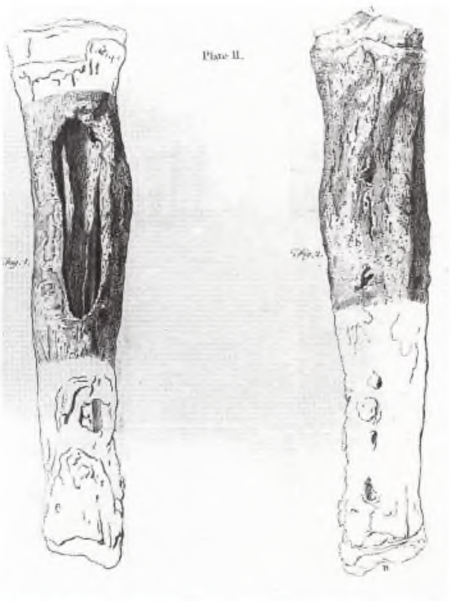

Figure 5.2 An anterior and posterior view of a chronically infected tibia with a well-developed involucrum surrounding a large sequestrum. From William Hunter, "An Account of a Diseased Tibia," *Medical Observations and Inquiries* 2(1762): 303–6, pl. 2.

response to the inflammation associated with infection (figures 5.1 – 5.2). The space between the sequestrum and the involucrum is filled with granulation tissue and pus, which drains to the outside through an ulcer or a fistula. Many of the older descriptions of osteomyelitis are found under the heading of either *ulcers* or *fistulae*. An example of the clinical presentation of chronic draining osteomyelitis of the tibia is seen in the painting by Simon Vouet (1582–1641) (figure 5.3).

The importance of the loss of circulation in the formation of a sequestrum was well known to the ancients. Hippocrates (460–375 B.C.), in describing injuries to the skull, comments:

For a piece of bone which is quickly dried and converted, as it were into a shell, is most readily separated from the rest of the bone which retains its blood and vitality; for, the part having become exsanguinous and dry, more readily drops off from that which retains its blood and is alive.[2]

His familiarity with the clinical problem is shown in one of his aphorisms: "When ulcers continue open for a year or upward, there must necessarily be exfoliation of bone, and the cicatrices are hollow."[3]

The presence of a sequestrum was determined by probing the ulcer or fistula. A variety of probes are described by Suśruta. Some of these were made of metal, but soft probes of the young shoots of plants were also used.[4] Students were trained in the use of such probes by practicing on worm-eaten wood, bamboo, reeds, or dried bottle gourds.[5] Albucasis (936–1013), in his work *On Surgery and Instruments*, described his armamentarium of probes.

And this is the shape of the probes; they are also called burud.

There are three kinds of this, too: large, medium, and small. They are suitable for exploring tumours, wounds, fistulas, and sinuses, to see what is inside them such as bones, etc. They are made round, polished, and smooth, like packing-needles, of Chinese copper or of white copper, or of brass, silver, or iron. The best are those made of white copper. Sometimes probes are made of black lead, for investigating fistulas whose deeper course is devious; so that by reason of their softness they can adapt themselves to curves. Of these, too, there are three varieties: the long, the medium, and the short, proportioned to the requirement of the depth of every fistula. Their thickness also should be proportioned to the width or narrowness of the fistula.[6]

Having probed and defined the extent of the fistula, Celsus (25 B.C.–A.D. 50) advised an operation.

Again, for fistulae which penetrate so deeply that a medicated bougie cannot be passed down to the ends, or those which are tortu-

Figure 5.3 A painting by Simon Vouet (1582–1641) showing a patient with chronic draining ulcers of the lower leg, suggesting a chronic osteomyelitis of the tibia. From Eugene Hollander, *Die Medizin in der klassichen Malerei* (Stuttgart: Ferdinand Enke, 1903), fig. 65.

ous or multiple, surgery has the advantage over medicine; and there is less trouble if the fistula runs horizontally under the skin, than when it tends directly inwards. Therefore if it lies horizontally under the skin, a probe should be introduced and cut down upon. When there are bends, these are followed up in the same way with the probe and knife; so also when they present multiple branchings. When the end of the fistula is reached, all the callus should be cut out, then pins are inserted through the skin margin, and agglutinating medicaments spread over all. But if it runs straight inwards, after its chief direction has been explored by means of the probe, that cavity ought to be excised, then a pin is to be inserted through the skin opening, and agglutinating medicaments applied as above; or if there is more corrupt ulceration, which is at time the case when there is disease of the bone, after the bone has been treated, suppuratives are put on.[7]

Albucasis described his procedure as follows:

If the bone be the cause of the fistula, and you are sure of that, then examine the fistula and open it up in the way I have told you, if there be nothing in the way like a blood vessel or nerve or important organ, as we said. And if the the bone is laid bare to you and there be in it some corruption and blackening, then scrape it until all corruption be removed; then put on dressings that will encourage granulation, until it be healed. If it does not heal but discharges pus in the way it did before, then you may know that you have not managed to extirpate the corruption completely. Therefore you must

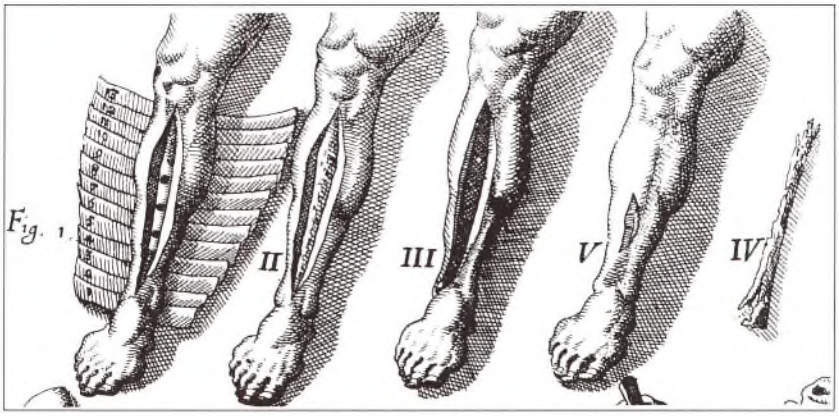

Figure 5.4 An illustration of the procedure for sequestrectomy. From Johannes Scultetus, *Armamentarium chirurgicum* (Ulm, 1563), pl. 27.

expose it again and with the utmost diligence carry out the scraping and cleaning of it. Then dress it; and if it heals, good; if not, then you may know that this corruption is very deep-seated in the body and out of reach, and there is nothing you can do for it but leave it to nature. If the diseased bone be a small one, and it be possible for you to extract it, then do so with a pair of fine forceps suited to the purpose. And if there be a number of bones then you must accurately carry out the extraction of all of them, and spare no effort to ensure that none is left.[8]

Surgeons from antiquity to the end of the eighteenth century made no real distinction between bone infections arising as a result of open fractures and those arising from hematogenous osteomyelitis. Their chief concern was with the chronic stage of drainage: sequestration and involucrum formation. Their diagnostic tool was the probe; their operations consisted of incision and drainage, with removal of the sequestra if possible. Johannes Scultetus (1595–1645) has given us a good illustration of how extensive such an operation could be (figure 5.4).

A good early account of a patient with acute hematogenous osteomyelitis with a spontaneous resolution was given by Alexander Mackenzie in 1760.

The bone herewith sent, is seven inches and a half of the thigh bone of William Baxter, at this time miller, in the mill of Unthank, in the parish of Duffus, in the shire of Elgin, who, when a boy of thirteen years old, got a blow on his thigh at school, of which he at first hardly complained; but in a few months he began to have pain in that thigh, it inflamed, swelled, and appeared to have matter in it.

The parents being poor, no surgeon was called, and the boy was allowed to linger for a great while. At length, the matter made its way through the skin, by a small opening, on the interior part of the *thigh, about three inches above the joint of the knee, and continued spueing out large quantities of thin sanies matter for eighteen or twenty months.*

At length, the hole in the skin enlarged, and the point of a bone began to appear very sharp and rough, which hurt him much, when any thing catched hold of it, as his breeches often did; for it is to be observed that the boy, for the most part, continued walking to school, with no other assistance than a stick in his hand. After two years and a half distress, as he lay a-bed one morning, he felt the bone looser and farther without the skin than ordinary; upon which he gave it a strong pull, and brought away this very bone: a pretty large hemorrhage ensued, but the wound in the thigh healed in a very short time; and he has never since found the least inconvenience.[9]

William Bromfeild (1712–1792) gave a good account of the diagnosis and treatment of hematogenous osteomyelitis.

It is universally allowed, that this disease takes its rise from matter being formed in the diploe, or in the marrow; whenever obstruction is begun in the vessels expanded on, or terminating in, the medullary cysts, the consequence will be inflammation, and if not early removed, will form matter; for this reason, I generally called this case abcessus in medulla. Whenever then a patient complains of a dull, heavy pain, deeply situated in the bone, possibly consequent to a violent blow received on the part some time before, and though at the time the patient complains of this uneasiness, within the bone, the integuments shall appear perfectly sound, and the bone itself not in the least injured, we have great reason to suspect an abcessus in the medulla. Children of a bad habit of body, though they have not suffered any external injury, will often become lame, and complain of the limb being remarkably heavy, and though not attended with acute pain, yet, the dull, throbbing uneasiness, is constant. If rigors happen during the time the patient labours under this indisposition, it generally implies that matter will be formed within the substance of the bone. On the age of the patient, and the solidity of the bone, will in a great measure depend the next alarming symptoms, to those who are not acquainted thoroughly with the case, and the constitution of the patient, as mothers and nurses are often inattentive to children on their first complaining of pain, and heaviness in a limb, if after rubbing it with their hand a few minutes, the child, amused by some new toy or play-fellow, think himself easier, the good women, as they cannot see any thing wrong, determine it a growing pain, as they call it; but, soon after, the extremities of the bone formerly complained of, begin to swell, or possibly throughout its whole extent, it becomes inlarged; a surgeon is then sent for, who, if, a man of experience, will know this to be an abcessus in medulla, or true spina ventosa, as it is called: if neither of these symptoms should

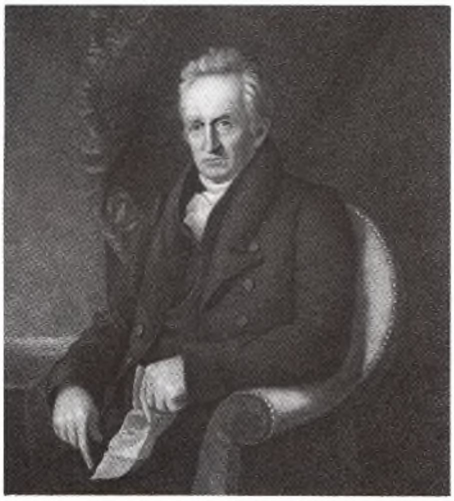

Figure 5.5 Nathan Smith (1762–1829). From Nathan Smith, *Medical and Surgical Memoirs* (Baltimore: Wm. A. Francis, 1831), frontispiece.

be consequent to the first complaint, the great insensibility of the bone in some subjects, will prevent that acuteness of pain usual in other parts, where matter is formed, though the acrid matter is eroding the bone during the whole time it is contained within it. This matter at length having made its way through, arrives at the periosteum, where it creates most violent pain, as well from its sharpness, as from its increased quantity, occasioning an extension of the membrane, which I declare inelastic. The integuments then become swelled and inflamed, and have a sort of emphysematous feel. On being examined, by pressure, from part of the matter retiring into the bone: from this appearance to the touch, most likely the name of ventosa was added to the term spina. When we are assured of matter being under the periosteum, we cannot be too early in letting it out, as it will save a considerable deal of pain to the patient, though probably not be of any considerable advantage in respect to the carious bone; for, as I have more than once before observed, where the fluids in general are vitiated, no chance of cure can be expected from topical remedies, but where the constitution is mended, nature will sometimes astonish us in her part; as the carious bone will be thrown off from the epiphyses, or, the teredines will be filled up by ossific matter, that flows from the parts of the bone where some of the spinae have come away.

If proper medicines are given, the children well supported, and the parts kept clean and dry, patience and perseverance will frequently give great credit to the surgeon. And from my dislike to amputate, where the disorder is not merely local, I have had my proportion of honor in perfecting a surprizing cure, without any farther pretentions to superior skill than what I have just related. In case it should have been thought adviseable to apply the head of a trephine at the upper and lower extremities of the tibia, to give free discharge to the matter, the washing it away, as well as the small crumblings of the carious bone, by means of detersive and drying injections, I have known to be greatly contributory to the curing of this kind of caries, after the habit of body in general had been mended.[10]

In the United States, the subject of acute hematogenous osteomyelitis was discussed thoroughly by Nathan Smith (1762–1829) (figure 5.5). One of the greatest of early American surgeons, Smith was born in the farming community of Rehoboth, Massachusetts, and raised in Vermont.[11] He became the student of the local doctor and worked as his apprentice for three years before establishing his own practice in a nearby town. After two years of practice he entered the newly established Medical Institute of Harvard, of which he became the seventh graduate in 1790. He returned to his practice near Hanover, New Hampshire, and became involved with the establishment of a medical school at Dartmouth College. In order to further his education, he traveled to Edinburgh and London in 1796–97. In addition to establishing the Dartmouth medical school, Smith had an active role in the establishment of medical schools at Yale University, Bowdoin College, and the University of Vermont. Although he is most widely known for his accurate account of typhoid fever, his description of hematogenous osteomyelitis is a classic.

Necrosis commences with an acute inflammation, either in the bone itself or its investing membrane, accompanied with acute pain, not always at first in the part affected, but often felt most severely in the joint nearest the disease. In a day or two, however, it generally leaves the joint, and permanently locates itself in the part inflamed.

Almost from the first commencement of the pain, there occurs severe symptomatic fever of the inflammatory character. The local affection generally terminates in suppuration, frequently as soon as the fourth or fifth day, and this event, if it occur, is rarely protracted beyond the tenth or twelfth. The matter is at first deposited between the external periosteum and the bone. When the shafts of the long bones are the seats of disease, about the same time that matter is deposited beneath the external periosteum, there is formed a corresponding collection between the internal surface of the bone and the membrane surrounding the medullary substance, so that there then exist two collections of matter bathing the opposite sides of the walls of the bone. This fact, which I deem of great importance, as being essential to the correct treatment of the disease, I have ascertained in repeated instances, by the operation which I have performed for its relief, namely, the trepanning of the bone.

Very soon after the attack, the whole limb swells, but there is no marked tumefaction immediately in the part affected, till after the matter makes its escape from the periosteum, and is diffused beneath the adjacent soft parts. Whenever this occurs, the extreme pain and symptomatic fever, which till then have continued unabated, in some degree subside, but do not entirely leave the patient.

When this kind of inflammation attacks the spongy bones, the matter is at first collected on both sides of the external lamella, or plate of compact bone, which covers the cells, so that it is similar to the same disease in the long bones, except that in the latter the matter within the bone is lodged between the medullary substance and the walls of the bone, the medullary substance not being affected or penetrated by the matter.

The death of a portion of the bone, in this disease, does not appear to arise from any extraordinary malignity in the inflammation, nor from its exerting any peculiar lethiferous influence upon the part affected, as some specific diseases destroy the parts which they attack. Abundant cause for the death of the part is found in the

Figure 5.6 Benjamin Collins Brodie (1783–1862). From Timothy Holmes, *Sir Benjamin Collins Brodie* (London: T. Fisher Unwin, 1898), frontispiece.

insulation of the bone, effected by the accumulation of matter on both sides of its parieties, and the consequent destruction of those vessels which, from the two periostea, furnish it with blood and nutrition, so that the denuded portion recieves no vessels but those extremely attenuated ones, which permeate it from the surrounding margin of healthy bone. These last being insufficient for its nutrition, it consequently perishes. Nature then sets a process of ulceration for the separation of the dead portion, and the evacuation of the matter contained within it, this occupying a greater or a less time, as influenced by circumstances. The dead and insulated bone, from its indestructible nature, remains as a foreign body in the living parts, until, by the recuperative efforts of nature, it is dislodged entire and rejected from the system; or, being constantly bathed in the secretions which protect the surrounding parts from its contact, is gradually dissolved and wasted away; or, finally, is removed by art.[12]

Smith recognized that the disease was almost exclusively confined to children and adolescents, and most commonly involved the tibia, the femur, and the humerus.

One of Smith's British contemporaries, Benjamin Collins Brodie (1783–1862) (figure 5.6), described a form of osteomyelitis characterized by the formation of a chronic abscess in the bone.

The whole of the lower extremity of the tibia was harder and more compact than under ordinary circumstances, in consequence, as it appeared, of some deposit of bone in the cancellous structure, and in its centre, about one-third of an inch above the ankle, there was a cavity of the size of an ordinary walnut, filled with a dark-coloured pus. The bone immediately surrounding this cavity, was distinguished from that in the neighbourhood by its being of a whiter colour, and of a still harder texture, and the inner surface of the cavity presented an appearance of high vascularity. The ankle joint was free from disease.[13]

Based on this observation, Brodie subsequently successfully treated several patients by trephining the bone and draining the abscess.

Brodie studied medicine in London and became a student of Sir Everard Home (1756–1832), the brother-in-law of John Hunter.[14] His surgical career was spent at St. George's Hospital, London. His early work in physiology won him election to the Royal Society, and he was one of the few medical practicioners to serve as its president. Following the death of Astley Cooper (1768–1841), Brodie was the premier surgeon in London.

The term *osteomyelitis*, derived from the Greek words for bone and marrow, was given to this condition by Auguste Nélaton (1807–1873) (figure 5.7).[15] Nélaton, one of the leading surgeons of Paris, practiced at the Hôpital Saint Louis with his colleague

Figure 5.7 Auguste Nélaton (1807–1873). From *Am J Surg* 14(1931): 690.

Figure 5.8 Edouard Chassaignac (1805–1879). From *Am J Surg* 112(1966): 957.

Joseph-François Malgaigne (1806–1865). While his fame has dimmed, we should remember Nélaton kindly, for he was the inventor of the rubber urethral catheter. In 1852 Edouard Chassaignac (1804–1879) (figure 5.8) described the findings in a case of osteomyelitis in a two-year-old child. He commented on the occurance of fat droplets in the pus drained from the subperiosteal area and on explained that the epiphysis was involved because of blood vessels that extended across the epiphyseal plate.[16] Chassaignac was born and educated in Nantes before going to Paris, where he became a surgeon for the Central Bureau of Hospitals. He made major contributions to the treatment of surgical infections, the most important of which was the introduction of perforated rubber drains.[17] Albert Lucke (1829–1894) of Strasbourg gave a good account of his experience with the diagnosis and treatment of twenty-four patients with hematogenous osteomyelitis immediately prior to the discovery of the role of bacteria in this disease by Robert Koch (1843–1910).[18]

A rare consequence of prolonged chronic drainage from a sinus tract that complicates osteomyelitis is a malignant change in the epithelium lining the tract. This was reported in 1835 by Caesar Henry Hawkins (1798–1884) in a paper entitled "Cases of Warty Tumours in Cicatrices."[19] Among the seven cases were two tumors arising in scars from old floggings, two in old burn scars, two in cases of chronic osteomyelitis, and one in an old wound scar. He described the local process as follows:

After the tumour has become solid and prominent, a new action takes place in it, and the tumour ulcerates and sloughs alternately, with a great deal of pain and suffering, and it is destroyed down to its basis, so as to present the appearance of a foul excavated ulcer, except in its circumference, where the skin is raised, thickened, and everted, and from time to time warts are generated, which again ulcerate and slough, till the patient becomes gradually worn out by suffering, but without having at all the sallow and peculiar aspect of a person dying of a malignant disease.[20]

The tumors arising in chronic draining sinuses are sometimes called *Marjolin's ulcer* after Jean Nicholas Marjolin (1780–1850). However, the three cases that he described all occurred in the scars of old burns.[21] When squamous cell carcinoma arises in a chronic draining sinus, the change can be anticipated by an increase in a foul discharge and the appearance of an indurated proliferative edge about the ulcer.[22] Fibrosarcomas and even a reticulum cell sarcoma have been reported as occurring under these circumstances.[23]

Until the final quarter of the nineteenth century, surgeons were confused about the etiology of hematogenous osteomyelitis, even though they understood its natural history. This situation

Figure 5.9 Carl Garré (1857–1928). From *Ciba Zeit* 9(1960): 3307.

was quickly altered by Robert Koch's publication (1843–1910) in 1878 of his paper on the etiology of wound infections, which for the first time described the role of specific bacteria in the etiology of infections.[24]

In the same year, J. Rosenbach, a surgical assistant in the Poli-Klinik in Göttingen, published his work on the experimental production of osteomyelitis in rabbits, dogs, and sheep by the injection of small amounts of pus into the bone marrow.[25] The results resembled spontaneous osteomyelitis in every way. He concluded that in spontaneous osteomyelitis the infection was carried to the bone marrow by the bloodstream and that spontaneous osteomyelitis was a specific infectious disease entity. In 1883, Becker, a young assistant at the state department of health in Berlin, using stringent antiseptic precautions, cultured the same organism from five different cases of osteomyelitis.[26] The cultures produced orange-colored colonies and appeared under the microscope to be micrococci. Giving solutions of these cultures intravenously into rabbits, guinea pigs, and mice failed to produce osteomyelitis unless the animals had a fresh fracture or a fresh contusion. Based on these experiments Becker contended that osteomyelitis was caused by a specific microorganism, which we now know as *Staphylococcus aureus.* His work was promptly supported by Fedor Krause (1857–1937), who was working at Richard Volkmann's clinic in Halle, and Paul Kraske (1851–1930) in Freiburg.[27] Carl Garré (1857–1928) (figure 5.9) thoroughly summarized all of this early work and discussed osteomyelitis and its complications under the following headings: (1) *Periostitis albuminosa*, (2) the subacute form, (3) the sclerosing, nonsuppurative form, (4) the bone abscess, (5) the recurrent form, (6) primary osteomyelitis in adolescents, (7) multiple osteomyelitis, (8) disease of the epiphyses, (9) epiphyseal separation, and (10) spontaneous fracture.[28] The third variety, the sclerosing, nonsuppurative form, has been named *Garré's osteomyelitis.* Garré was born in Switzerland and educated in Zurich, Leipzig, and Bern. He taught both surgery and bacteriology in Basel and held a variety of professorial chairs before settling in Bonn in 1907. He made substantial contributions to the development of sterile surgical techniques for use in the operating room and his work touched upon all of the great surgical problems of his era.

Erich Lexer (1867–1937) reported on some interesting experiments in 1896.[29] He injected suspensions of *Staphylococcus aureus* into the ear veins of rabbits. The ears were cut off immediately following injection to avoid complicating the experiments with local abscesses at the site of injection. He found that the first evidence of bone infection was visible in the metaphyses of the long bones with subsequent involvement of the marrow cavity and subperiosteal regions. An important study on the mechanism

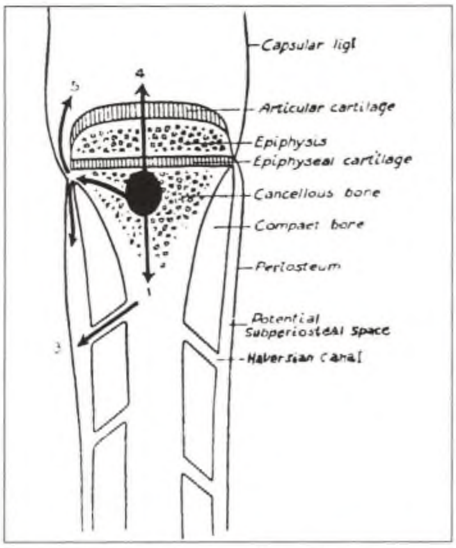

Figure 5.10 Diagram illustrating the routes of the spread of infection from the metaphyseal nidus to the joint and the subperiosteal region. From Clarence L. Starr, "Acute Haematogenous Osteomyelitis," *Arch Surg* 4(1922): 569.

of the lodging of bacteria circulating in the bloodstream in the metaphyseal areas of the rabbit tibia was carried out in Japan by Teruo Hobo at the University Clinic in Kyoto.[30] The first stage involved the description of the circulation in the arterioles and venules in the area. The next stage was a study of the localization of foreign bodies in these vessels using a suspension of India ink given intravenously. The last stage consisted of the intravenous injection of suspensions of staphylococcus aureus obtained from furuncles with the production of acute hematogenous osteomyelitis. His work on the localization and spread of infection in acute hematogenous osteomyelitis is summarized in figure 5.10.

During the next twenty years, acute hematogenous osteomyelitis became well defined as a clinical entity and its pathogenesis became more clear. Clarence L. Starr (1867–1920) of Toronto reviewed the problem in 1922 and pointed out that early diagnosis depended upon the clinical findings because X-rays were of no value until after bony changes had occurred.[31] He advocated immediate incision of the periosteum for drainage and metaphyseal drilling. In late cases he believed that after establishing efficient drainage, it was best to wait until sequestration and involucrum formation had occurred. At this time sequestrectomy, saucerization, and packing with iodoform gauze were to be performed. After caring for ninety-eight patients with osteomyelitis, six of whom died, Charles E. Farr made the following observations:

1. *Acute osteomyelitis in children is a manifestation of septicemia with pyaemic abscesses in the bones.*
2. *The portal of entry for these organisms is frequently the skin.*
3. *The probable underlying cause is a state of lowered vitality and resistance to infection.*
4. *Local trauma plays a minor, if any, role in the causation.*
5. *Early recognition and drainage will save a large proportion of the cases.*
6. *As in all other infections, the general resistance of the patient and the virulence of the invading organism are the two essential factors.*[32]

By 1924 bacteriological methods were sufficiently developed so that in a group of cultures from four hundred patients with acute hematogenous osteomyelitis the organisms were able to be identified as follows: *Staphylcoccus aureus*, 78 percent; *Staphylococcus albus*, 2 percent; *Streptococcus pyogenes*, 6 percent; and *Pneumococcus sp*, 14 percent.[33] While the tibia and the femur were the bones most frequently involved, infection could occur in any bone in the skeleton.[34] The best review of our knowledge of osteomyelitis in the preantibiotic era is that of Abraham O. Wilensky of New York City.[35]

Osteomyelitis caused by *Brucella abortus* was first reported in 1932.[36] The relationship of osteomyelitis caused by the salmonella organisms with sickle cell disease was not described until 1950.[37] We should not forget that congenital syphilis also can present a picture of atypical osteomyelitis with periostitis, osteitis, and metaphyseal changes.[38]

One important cause of osteomyelitis has been eradicated. One of the complicatons of smallpox was a bilaterally symmetrical osteomyelitis primarily involving the upper extremities, and occasionally the lower. First described by Alfred Bidder in 1873, such cases were familiar to Paré.[39]

Roland Marie, Merchant Spectacle-maker, dwelling near the Palais, took me to his daughter, aged four years and two months. Her whole body was covered with pustules and smallpox. The bones of the arms and legs were abscessed, putrid and fractured, accompanied by a high fever. I did not want to touch her; the next day she died.[40]

The natural history of *osteomyelitis variolosa* has been well presented by Peter Cockshott and Malcolm MacGregor.[41] Osteomyelitis can also result from an infection by the vaccinia virus.[42] The adult form of acute hematogenous osteomyelitis was not well defined clinically until the paper by Isadore Zadek in 1938.[43]

There were two major problems facing the surgeon in the early management of a patient with acute hematogenous osteomyelitis. The first was the establishment of the diagnosis and the localization of the area of infection. This had to be done solely on the clinical history and examination. X-rays were of value only to rule out other diseases or injuries. The second was the timing and extent of the surgical intervention in a patient who might be very ill with all of the signs and symptoms of septicemia.[44] Lexer described the operation as follows: "The incision should not damage the function of the limb and should be 'as large as necessary and as small as possible,' carried out with great care to provide the best drainage."[45] He advocated early drainage before extensive tissue damage had occurred. The results in the management of 110 patients were presented by John Wilson and Francis McKeever in 1936.[46] The mortality rate in patients with multiple diffuse infections was 25 percent; in single diffuse infections, almost 10 percent. In patients with Brodie's abscesses or sclerosing osteomyelitis, there were no deaths. Serious complications from osteomyelitis included bronchopneumonia, bacterial endocarditis, brain abscess, meningitis, and lateral sinus thrombosis. In some reports of groups of patients with osteomyelitis, the use of staphylococcus antitoxin was reported to be of benefit in reducing the mortality in the acute stage.[47]

Once the decision to carry out surgical drainage had been made and the operation performed, the question of the after care of the wound became important. The methods used all had their origin in experiences in World War I. The Carrel-Dakin method, named for Alexis Carrel (1873–1944) and Henry Drysdale Dakin (1880–1952), and which consisted of continuous irrigation of the wound with a dilute solution of sodium hypochlorite, had been widely used in the treatment of the wounded.[48] This method was easily adapted for civilian use. Its success depended upon reducing the bacterial population in the wound to a minimum by means of the local application of a bacteriocidal solution, at which time the wound would be closed secondarily or covered with a split-thickness skin graft. The patient was hospitalized and underwent daily wound dressing until the wound could be closed. Maggots, raised under sterile conditions, were introduced into granulating, suppurating wounds, to perform microdebridement and prepare the wound for closure.[49]

The method introduced by H. Winnett Orr (1877–1956) in 1923 was based on his experience in France during World War I.[50] As carried out in civilian practice by Arthur Steindler (1878–1959) at the University of Iowa, it consisted of

> *1) Immediate adequate drainage of the osteomyelitic focus in whatever stage it is encountered.*
>
> *2) Maintaining at rest the inflamed part by the application of a plaster cast, aided, if necessary, by ice tongs and other methods of skeletal fixation.*
>
> *3) Keeping the drained area wide open by means of a sterile vaseline pack.*
>
> *4) Primary asepsis, avoiding the use of irritating antiseptics in the wound.*
>
> *5. Postoperative care, emphasizing rest without antiseptic dressings which usually increase and complicate infection.*
>
> *6. The maintainance of all injured parts, bones and soft parts, in their correct anatomical position during the entire period of healing.*[51]

Orr promoted his method tirelessly.[52] When he lectured before the orthopedic section of the New York Academy of Medicine on 18 November 1927, the discussion by prominent New York orthopedic surgeons was generally supportive.[53] The method became the procedure of choice for the treatment of hematogenous osteomyelitis at the Cook County Hospital in Chicago.[54] There was a revival of interest in Orr's method with the onset of the Spanish Civil War, the prologue to World War II, when it was taken up by José Trueta (1897–1977) and widely used, with modifications, for both civilian and military casualties.[55]

A success by any of these methods was considered to be a clean, granulating wound. Since secondary closure was not widely used, this meant a wound that filled in slowly by granulation tissue and epithelialized from the edges. The wounds took months to heal; the scar was thin and easily broke down. As early as 1902, John P. Lord (1860–1940) demonstrated that the healing of such a wound could be speeded up by the use of small pinch grafts.[56] This method became very useful.[57] Sometimes split-thickness skin grafting became the first stage of a reconstructive procedure.[58] The wound was cleaned out and closed with split-thickness grafts. Following healing, the wound was reexcised, filled with bone chips, and covered with a full-thickness graft. All kinds of sliding, pedicle, and cross-leg full-thickness grafts were employed.[59] Combinations of muscle flaps and split-thickness skin grafts were also used.[60] An interesting method of grafting bone defects and obtaining skin coverage at the same time was pioneered by L. J. Papineau of Montreal, whose technique consisted of thorough cleansing of the wound, followed a week or two later by packing the defect with bone chips and then covering these grafts with a split-thickness skin graft.[61]

A major advance in the control of infection occurred in 1935 with the discovery of prontosil by G. Domagk.[62] The discovery of sulfanilamide, the active principle of prontosil, followed almost immediately.[63] John S. Lockwood (1907–1950) concluded that while the sulfonamide drugs were bacteriostatic, surgical treatment, in the form of drainage, was still very important.[64] Lockwood's opinion on the local use of sulfonamide crystals in wounds, a technique that had widespread support at the time, was that

local sulfonamide applications are probably useful in the first management of contaminated wounds between injury and definitive surgical treatment, and in preparing open granulating wounds for application of skin grafts, but are of little demonstrable value in the treatment of wound suppuration or invasive infection.[65]

Bl. Kovacevic had good results in the treatment of chronic osteomyelitis by carrying out sequestrectomy and packing the wound with a mixture of sterile plaster of paris and sulfonamide crystals.[66] The use of the sulfonamide drugs either locally or systemically in patients with acute or chronic osteomyelitis quickly gave way to the next wave of antibiotic drugs.

While Alexander Fleming (1881–1955) had reported the antibacterial action of penicillium molds in 1929, it was not until 1940 that Ernest B. Chain (1906–1979) and his colleagues reported the isolation of the antibiotic penicillin.[67] The use of penicillin was confined initially almost exclusively to the treatment of casualties in the armed forces, with little becoming available for use by civilians until after 1946. Champ Lyons (1907–1965) evaluated the use of penicillin in the United States Army and

Figure 5.11 Georg Axhausen (1877–1960). From *Zentralbl Chir* 85(1960): 561.

considered it to be of value as an adjunct to surgical treatment.[68] William A. Altemeier (1910–1983) of Cincinnati was one of the first to use penicillin in civilian practice in the treatment of acute hematogenous osteomyelitis.

If the diagnosis was made early and penicillin treatment instituted promptly without surgical drainage, both the general and local infections were brought under control so thoroughly that a minimal amount of residual bony damage resulted. Moderate delay in diagnosis and treatment increased the extent of the bony damage, but the infection was nevertheless quickly arrested without the aid of drainage and without sequestration. If small localized abscesses developed, they were treated very satisfactoring by aspiration followed by injection of a solution of penicillin. If large abscesses developed, prompt drainage by surgical incision was required. Delay in diagnosis and treatment not only increased the degree of bony damage but favored the development of large abscesses, sequestra and metastatic visceral infections.

Penicillin is a powerful and effective chemotherapeutic agent in the treatment of acute osteomyelitis. When administered early and in adequate amounts, it reduces the mortality and morbidity, brings the infection under control, minimizes local destruction of bone and resultant deformities, permits spontaneous removal of necrosed bone and healing, and makes possible early return of normal or nearly normal function.[69]

V. H. Ellis (1901–1953), an orthopedic colleague of Fleming and the first orthopedic surgeon to have an extensive experience with the use of penicillin in the treatment of bone infections, agreed with Altemeier but also emphasized the value of penicillin in the treatment of recurrent flares of old osteomyelitis.[70] He believed that all operations on patients with osteomyelitis should be carried out while the patient was receiving penicillin.

In the past fifty years the use of antibiotics early in the course of primary infections has cut down on the incidence of septicemia and tertiary infections of which acute hematogenous osteomyelitis is an example. For this reason acute hematogenous osteomyelitis has become a rare disease. When it does occur the decisions regarding diagnosis, localization, indication and timing of the surgical intervention, and long-term treatment remain difficult.

The older surgeons always thought of bone necrosis as being associated with sequestration, infection, pus, and draining sinuses. The idea that there could be bone death without associated infection, that is, aseptic necrosis, was not entertained. However, in 1914 Georg Axhausen (1877–1960) (figure 5.11), a professor at the hospital Charité in Berlin, advanced this concept on the basis of his observations of animal experiments and disease processes in patients.[71] Of particular importance to him was the fate of bone grafts, sterile pieces of bone without vascular connections placed into sites in bone under sterile conditions, that healed and were incorporated into the bone without becoming sequestra. By 1928 he had assembled a very convincing body of evidence to demonstrate that anemic infarcts did occur frequently in a wide variety of conditions, concluding, most significantly, that the changes in the epiphysis of the head of the femur described by Arthur Thornton Legg, Jacques Calve, and Georg Clemmons Perthes, were due to aseptic necrosis.[72] In Chicago, Dallas Phemister (1882–1951) cultured necrotic bone removed at operations in two cases of Kohler's disease, two cases of Legg-Perthes disease, and two cases of Kienbocks disease.[73] Streptococci were grown from these cultures in four of the six patients. He concluded that streptococci played an important role in the etiology of these conditions. The bacteriological methods and aseptic surgical technique used in 1936 had introduced an error into his findings. The very same year in a more comprehensive discussion of various types of conditions in which bone became devascularized, he concluded:

As previously stated, aseptic necrotic bone in continuity with living bone is gradually invaded and more or less completely replaced by new bone through the process of creeping substitution, unless it is too inaccessible and is broken down by traumatism.[74]

Osteomyelitis associated with open fractures has decreased in incidence in areas where prompt and efficient trauma care is available. The early use of antibiotics in the treatment of common infections in children has reduced the incidence of hematogenous osteomyelitis significantly. However, osteomyelitis complicating elective reconstructive operations such as joint replacement has become more frequent. Unfortunately the classical forms of osteomyelitis and all of their complications persist in areas of the world where medical care is lacking.

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CHAPTER SIX

Tuberculosis of the Bones and Joints

Tuberculosis is a generalized disease affecting primarily the lung, but it can also localize in the kidneys and other visceral organs. Tuberculosis of the bones and joints makes up about 1 percent of patients with tuberculosis. This disease, more than any other, influenced the development of orthopedics. Because of the very high incidence of bone and joint tuberculosis in children and adolescents, orthopedic surgeons became child-oriented out of necessity. The literature dealing with bone and joint tuberculosis is extensive. All of the great figures in the history of orthopedics studied and wrote about its manifestations and its treatment.

Tuberculosis is still one of the most important infectious diseases; it still affects people throughout the world. In addition to affecting man, it also occurs in both domestic and wild animals and birds. The microorganism causing tuberculosis in man, *mycobacterium tuberculosis*, was identified by Robert Koch (1843–1910) in 1882; *mycobacterium avian*, which occurs in birds, by Sebastiano R. Rivolta (1832–1893) in 1889; and *mycobacterium bovis*, which occurs mainly in cows, by Theobald Smith (1859–1934) in 1898.[1] While *mycobacterium avian* seldom occurs in man, infections with *mycobacterium bovis* are frequent, and *mycobacterium tuberculosis* can be spread to animals. Previous to the discovery of the etiology of tuberculosis, its various clinical syndromes had been described separately since antiquity and were well known. Because the incidence of tuberculosis was closely associated with malnutrition, alcoholism, and overcrowding, conditions that became very prevalent during the industrial revolution of the eighteenth and nineteenth centuries, it is not surprising that tuberculosis was very common. William Osler (1849–1919) quotes an old German axiom, "Everyone, at the end, has a bit of

Figure 6.1 John Hilton (1805–1878). From John Hilton, *Rest and Pain*, ed. E. W. Walls and Elliott E. Phillips in collaboration with H. J. B. Atkins (Philadelphia: J. B. Lippincott Co., 1950), frontispiece.

tuberculosis" (Jedermann hat am Ende ein bischen Tuberculose), to point out the large number of patients dying of all diseases in whom quiescent or active tuberculous lesions were found in the lungs at autopsy.[2] Tuberculosis remains a serious threat to public health.[3]

Bovine tuberculosis was the most serious disease in animals in the nineteenth century and its control required a massive effort.[4] Bovine tuberculosis commonly infected children and was the most important agent in the nonpulmonary forms of tuberculosis, especially tuberculosis of the lymph nodes, namely *scrofula*, and tuberculosis of the bones and joints. Bovine tuberculosis infections in humans declined quickly following the introduction of pasteurization of milk and the slaughter of infected cattle.

Prior to the introduction of chemotherapy, even under optimum conditions, the results of treatment of bone and joint tuberculosis were not good. Patients died as the result of chronic septicemia complicated by amyloidosis, tuberculous involvement of the lungs, kidneys, and bladder, or tuberculous meningitis.[5] Edward M. LaFond reported that in a group of 230 adults, mostly young men, with skeletal tuberculosis treated between 1928 and 1946, the death rate was 57 percent and the relapse rate was 39 percent.[6] The skeletal lesions were complicated by genitourinary tract and pulmonary tuberculosis as well as with multiple skeletal lesions.

Lacking any specific medical treatment physicians had to rely on the "the healing power of nature" (*vis medicatrix naturae*) and fell back on what was called "Natural Therapeutics," one of the chief elements of which, according to John Hilton (1805–1878) (figure 6.1), was "Rest—Physiological as well as Mechanical Rest."[7] John Hilton was educated at Guy's Hospital and began his career, as did so many of the British surgeons, by an intensive study of anatomy. He later became established as a surgeon and remained a fixture on the London scene until he retired from hospital practice in 1871. Hilton's Law, based upon his anatomical knowledge and clinical experience, states that

> *the same trunks of nerves, whose branches supply the groups of muscles moving a joint, furnish also a distribution of nerves to the skin over the insertions of the same muscles; and — what at this moment more especially merits our attention — the interior of the joint receives its nerves from the same source.*[8]

This explains very simply why in children with hip disease their first complaint of pain is referred to in the knee. Hilton elevated his doctrine of rest to the level of a religion and its bible was a series of lectures delivered at the Royal College of Surgeons of England in 1860, 1861, and 1862.[9] An example of the lengths he was willing to go to obtain his end is seen in his treatment of onanism, or excessive masturbation, perceived to be an important medical problem in the nineteenth century. "I know of no way to prevent onanism except by freely blistering the penis, in order to make it raw, and so sore that it can not be touched without pain. This plan of treatment is sure to cure onanism."[10] Hilton's doctrine of rest had no greater supporter than Hugh Owen Thomas (1834–1891), the enigmatic descendant of a line of Welsh bonesetters, whose concept of "enforced, uninterrupted, and prolonged rest" affected orthopedic and fracture treatment for the next one hundred years.[11].

In addition to rest, fresh air and sunshine were considered to be of great value. Osler made this comment regarding the treatment of tuberculosis:

In the majority of cases the treatment has to be carried out at home and often under adverse conditions. Still, much can be done if the patient is kept out of doors in the fresh air for the greater part of each day. In pulmonary tuberculosis neither the cough, the fever, the night-sweats, nor the haemoptysis contraindicates this rule. Only when the weather is blustering or rainy should the patient remain in the house. It is remarkable how quickly improvement in many instances follows this freah-air treatment. In cities the patient can be wrapped up and placed on a sofa or in a reclining-chair on the balcony or even in the yard.

The climatic treatment of tuberculosis is simply a modification of this plan. The requirements of a suitable climate are a pure atmosphere, an equable temperature not subject to rapid variations, and a maximum amount of sunshine. Given these three factors, and it makes little difference where a patient goes so long as he lives an outdoor life.[12]

As institutions for the care of patients with tuberculosis developed, all of them saw to it that there was enhanced nutrition, plentiful exposure to fresh air and sunshine, andrest to the affected area.

Typical of such institutions were the *établissements héliothérapeutiques* de Leysin in Switzerland, directed by Auguste Rollier (1874–1954). Situated in the Alps at an elevation of five thousand feet, the program for the treatment of bone and joint tuberculosis consisted of rest, fresh air, and exposure to the sun.[13] The results were impressive. Other hospitals, such as the Rothschild Hospital at Berck-sur-Mer on the English Channel near Calais (figure 6.2), and the Lord Mayor Treloar Cripples Hospital at Alton, took advantage of the bracing seacoast climate.[14] Dame Agnes Hunt gives an interesting description of the establishment of the country hospital near Baschurch in Shropshire in her autobiography.[15] This famous orthopedic children's hospital, which evolved into the Robert Jones and Agnes Hunt Orthopaedic Hospital, became the prototype of many such hospitals in Britain (figure 6.3). John B. Huber published a well-illustrated description of in-

Figure 6.2 The children of the *Institut orthopédique* of Berk, on the sands. From F. Calot, *Indispensible Orthopaedics* (London: Bailliere and Cox, 1914), facing p. 180.

Figure 6.3 Sunshine and open-air treatment at the Country Branch, Royal National Orthopaedic Hospital, Stanmore, Middlesex. From Frederick Watson, *Civilization and the Cripple* (London: John Bale, Sons & Danielson Ltd., 1930), facing p. 11.

Figure 6.4 An example of Pott's disease from ancient Egypt. From Schrumpf-Pierron, "Le mal de Pott en Egypte 4,000 avant notre ere," *Asculape* 23(1933): 295.

stitutions for the care of tuberculous patients as they existed at the beginning of the twentieth century.[16] The hospitals established especially for the treatment of bone and joint tuberculosis had different programs than those primarily for the treatment of pulmonary tuberculosis. They set the pattern for crippled children's hospitals for the next fifty years.

Tuberculosis of the spine typically produces a sharp angulation in the anterior-posterior plane of the spine at the point of maximum destruction of the vertebrae. This hunchback deformity is called a *gibbus*, from the Latin for *hump* or *hunch*. It is a more pronounced angulation than the gentle curve of a *kyphos*, from the Greek for *hump*. A classic example of kyphosis is the so-called *senile kyphosis*, which is commonly seen in older women and is caused by osteoporosis. An example of a gibbus deformity in the upper thoracic region is seen in the small statuette from ancient Egypt from the period 4000–3400 B.C. (figure 6.4). Henry Sigerist reviewed the material relating to the incidence of tuberculosis of the bone among the early Egyptians and concluded that it was a common disease.[17] Although there is no question that tuberculosis occurred in prehistoric America, whether the hunchbacked flute player of the southwestern United States, Kokopelli, represents a patient with such a deformity cannot be established.[18]

Hippocrates (460–377 B.C.) gave a good description of tuberculosis of the spine.

The vertebrae of the spine when contracted into a hump behind from the disease, for the most part cannot be remedied, more especially when the gibbosity is above the attachment of the diaphragm to the spine. Certain of those below the diaphragm are carried off by varices in the legs, more especially by such as occur in the vein at the ham; and in those cases where the gibbosities are removed, the varices take place also in the groin; and some have been carried off by a dysentery when it becomes chronic. And when the gibbosity occurs in youth before the body has attained its full growth, in these cases the body does not usually grow along the spine, but the legs and the arms are fully developed, whilst the parts (about the back) are arrested in their development. And in those cases where the gibbosity is above the diaphragm, the ribs do not usually expand properly in width, but forward, and the chest becomes sharp-pointed and not broad, and they become affected with difficulty of breathing and hoarseness; for the cavities which inspire and expire the breath do not attain their proper capacity. And they are under the necessity of keeping the neck bent forward at the great vertebra, in order that their head may not hang downward; this therefore, occasions great contractions of the pharynx by its inclination inward; for even in those who are erect in stature, dyspnea is induced by this bone inclining inward, until it be restored to its place. From this frame of body, such persons *appear to have more prominent necks than persons in good health, and they generally have hard and unconcocted tubercles in the lungs, for the gibbosity and the distension are produced mostly by the tubercles, with which the neighboring nerves communicate. When the gibbosity is below the diaphragm, in some of these cases nephritic diseases and affections of the bladder supervene, but abscesses of a chronic nature, and difficult to cure, occur in the loins and groins, and neither of these carries off the gibbosity; and in these cases the hips are more emaciated than when the gibbosity is seated higher up; but the whole spine is more elongated in them than in those who have the gibbosity seated higher up, the hair of the pubes and chin is of slower growth and less developed, and they are less capable of generation than those who have the gibbosity higher up. When the gibbosity seizes persons who have already attained their full growth, it usually occasions a crisis of the then existing disease, but in the course of time some of them attack, as in the case of younger persons, to a greater or less degree; but, for the most part, all these diseases are less malignant. And yet many have borne the affection well, and have enjoyed good health until old age, more especially those persons whose body is inclined to be plump and fat; and a few of them have lived to beyond sixty years of age, but the most of them are more short-lived. In some cases the curvature of the spine is lateral, that is to say, either to the one side or the other; the most of such cases are connected with tubercles (abscesses?) within the spine; and in some, the positions in which they have been accustomed to lie co-operate with the disease. But these will be treated of among the chronic affections of the lungs; for these the most suitable prognostics of what will happen in these cases are given.*[19]

The association of gibbus deformities with tubercles and with disease of the chest was made by Galen and by commentators on Hippocrates and Galen such as Jacques Dalechamps (1513–1588), Marcus Aurelius Severino (1580–1656) and Johann Zacharian Platner (1694–1747).[20] Part of the difficulty we have in interpreting their comments lies in the meaning of the word, *tubercle*, the diminutive form of the Latin *tuber*, meaning lump or swelling. The word did not assume a specific connotation in relationship to the disease tuberculosis until the publications of Franciscus Sylvius (1614–1672) and Gaspard-Laurent Bayle (1774–1816).[21]

In 1779 Percivall Pott (1714–1788) and Jean-Pierre David (1737–1784) both published descriptions of spinal tuberculosis. David was the professor of anatomy and surgery at the medical school and chief surgeon at the city hospital in Rouen. In 1778 the Royal Academy of Surgery in Paris offered a prize for the best paper on the subject of the effects of motion and rest on disease and the indications for the use of each in the treatment of surgical conditions. David's prize-winning essay was published the following year.[22] It contains an accurate description of spinal tuberculosis and deals with the clinical findings, the course of the disease and the pathological findings at autopsy. David describes the resolution of a psoas abscess and the recovery of a patient treated by prolonged rest in bed. His treatment was based on the use of rest and good supportive care. He inveighed against the surgical drainage of any associated abscesses.

> *The surgeon who makes this opening, and who sees that he has given issue to a great quantity of matter, confined for a long time in swellings of this kind, congratulates himself upon an event which he thinks cannot but turn out for the good of his patient; but the patient, who for some months past had experienced no evident degree of fever, who suffered but little, who had perhaps preserved his appetite, who slept, and who had complained of no other symptom but that he could not keep his back upright, is far from being relieved by this operation, at least if he be, the relief is not of long continuance; for the matter forming the tumour, which at the time of the opening was white as milk and without smell, soon contracts a considerable stench, a fever comes on, the pulse becomes quick and small, and the patients pretty frequently die towards the thirteenth day. The body is afterwards opened, when a caries of two or three of the lumbar vertebrae, and often of part of the os sacrum, presents itself to the view; and after this discovery, the Surgeon is far from imputing to his own management the speedy death of the patient.*[23]

The recognition of the high mortality rate due to secondary infection following the opening of tuberculous abscesses led surgeons to be very conservative in their indications for such operations. This view was reinforced by the knowledge that the abscesses would resorb spontaneously if the process in the spine healed.

Pott was a student of Cheselden and the leading surgeon in London for many years.[24] His book, *Remarks on That Kind of Palsy of the Lower Limbs,* dealt with the neurological changes occurring in some patients with spinal tuberculosis.[25] His treatment consisted of a form of counter irritation in which several localized abscesses were produced in the soft tissue on either side of the spine by means of a inserting a foreign body, passing a seton, or with a chemical cautery (figure 6.5). He was able to report that some patients incapacitated by lower-limb paralysis could recover the use of the paralyzed limbs. One of Pott's colleagues extended the use of *issues* (the production of draining sores by the surgeon) to the treatment of other tuberculous joints, remarking that

> *an issue in any part of the body may be successfully employed as a constitutional remedy, in all cases of scrofula, and may probably be sufficiently powerful when it is applied in time, to prevent an attack of this disease, in constitutions predisposed to it.*[26]

Figure 6.5 A drawing showing the placement of the "issues" that Pott used in the treatment of tuberculosis of the spine. From L. Bellon, "Percivall Pott's Disease of the Spine, Discussed in Two Letters of J. Hunczovsky," *Med Hist* 16(1972): facing p. 79, fig. 1.

In a second book published in 1782, *Further Remarks on the Useless State of the Lower Limbs*, Pott drew the following conclusions:

1. *That the disease which produces these effects on the spine, and the parts in its vicinity, is what in general called the scrophula; that is, that same kind of indisposition as occasions the thick upper lip, the tedious obstinate ophthalmy, the indurated glands under the chin and in the neck, the obstructed mesentery, the hard dry cough, the glairy swellings of the wrist and ancles, the thickened ligaments of the joints, the enlargement and caries of the bones, &c. &c. &c.*
2. *That this disease, by falling on the spine and the parts connected with it, is the cause of a great variety of complaints, both general and local.*[27]

Both David and Pott were keen observers and had experience with the conditions they were describing. John Ridlon (1852–1936), of Chicago, in an article entitled "Jean-Pierre David: The Man Who Potted Pott," believed that David's work on tuberculosis of the spine was superior to Pott's.[28] This opinion is hard to sustain; both of their observations deserve attention. It is surprising, however, that the French have always referred to tuberculosis of the spine as the *mal du Pott* instead of the *mal du David*!

During Pott and David's era, surgeons were drawing closer to the realization that this spinal disease was part of a generalized condition. Pott associated it with scrofula, that is, tuberculous lymphangitis. Claude Pouteau (1725–1775) began a chapter on diseases of the spine by saying that "the gibbosity is very intimately associated with pulmonary phthisis." (La gibbosité a les plus intimes relations avec la phthysie pulmonaire.)[29]

It remained, however, for Jacques Mathieu Delpech (1777–1832) to establish the validity of this relationship and to suggest that Pott's disease be called *affection tuberculeuse des vertèbres.*[30] This distinction was very important because in most cases it separated scoliosis in its various forms from tuberculosis of the spine.

There is a touching story of a young patient with Pott's disease that illustrates some of the social aspects of tuberculosis and the empathy for the patients that was felt by many of their physicians. It was written in northern France in 1871 by a member of the German occupation forces who had a great familiarity with his subject.

Once upon a time there was a woman who had a child, a small, pale girl who was unlike other children. When the woman took the child for a walk, the people in the street stopped and whispered. When the little girl asked, "Why do they look at me so strangely?" the mother answered, "Because you wear such a very pretty new dress".

After a time, the mother died, and the child had no one to take her walking. She became very pale and did not grow. A year later her father remarried, and the little girl fearfully asked if she might accompany her stepmother shopping. The stepmother cruelly replied, "What would people say if they saw me with you? You're a hunchback and must stay at home".

The little girl often wondered about her hunch and about what might be inside of it. Since she was never permitted to go out-of-doors again, she grew gradually paler and weaker, and finally died. When an angel came to take her to heaven, she could not believe that hunchbacks could go to heaven. The angel smiled and showed her that there were two magnificent white angel's wings hidden in her hunch.[31]

This was one of many poems and stories written by Richard Leander, whose real name was Richard Volkmann (1830–1889), a professor of surgery and head of the surgical clinic in Halle.32 Remembered today primarily for his description of the ischemic contracture of the flexor muscles of the forearm, which bears his eponym, his contributions to the developing specialty of orthopedics were substantial. One of the earliest followers of Lister, he carried the technique of antiseptic surgery to the European continent and helped to popularize its use. He wrote important articles on the surgical treatment of tuberculosis, poliomyelitis, and the excision of joints. William Halsted (1852–1922) in a letter to William Henry Welch (1850–1934) gives this description:

Volkmann was tall, slender and animated, had reddish hair and wore flowing Dundreary whiskers and long mustaches. His costume at the first seance of the Congress, I recall vividly — swallow tailed coat, white silk waistcoat, bespangled with embroidered flowers, soft white shirt, flowing bright artist's tie and Scotch plaid trousers. He

Figure 6.7 A hyperextension frame used by Royal Whitman to treat tuberculosis of the spine. From A. H. Tubby, *Deformities including Diseases of the Bones and Joints*, 2d ed. (London: Macmillan & Co. Ltd., 1912), 2:146.

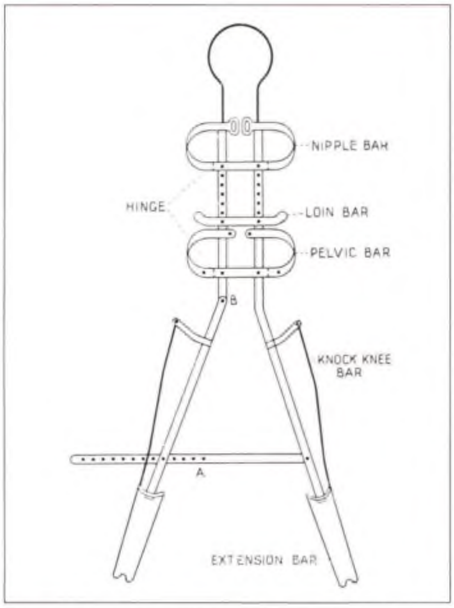


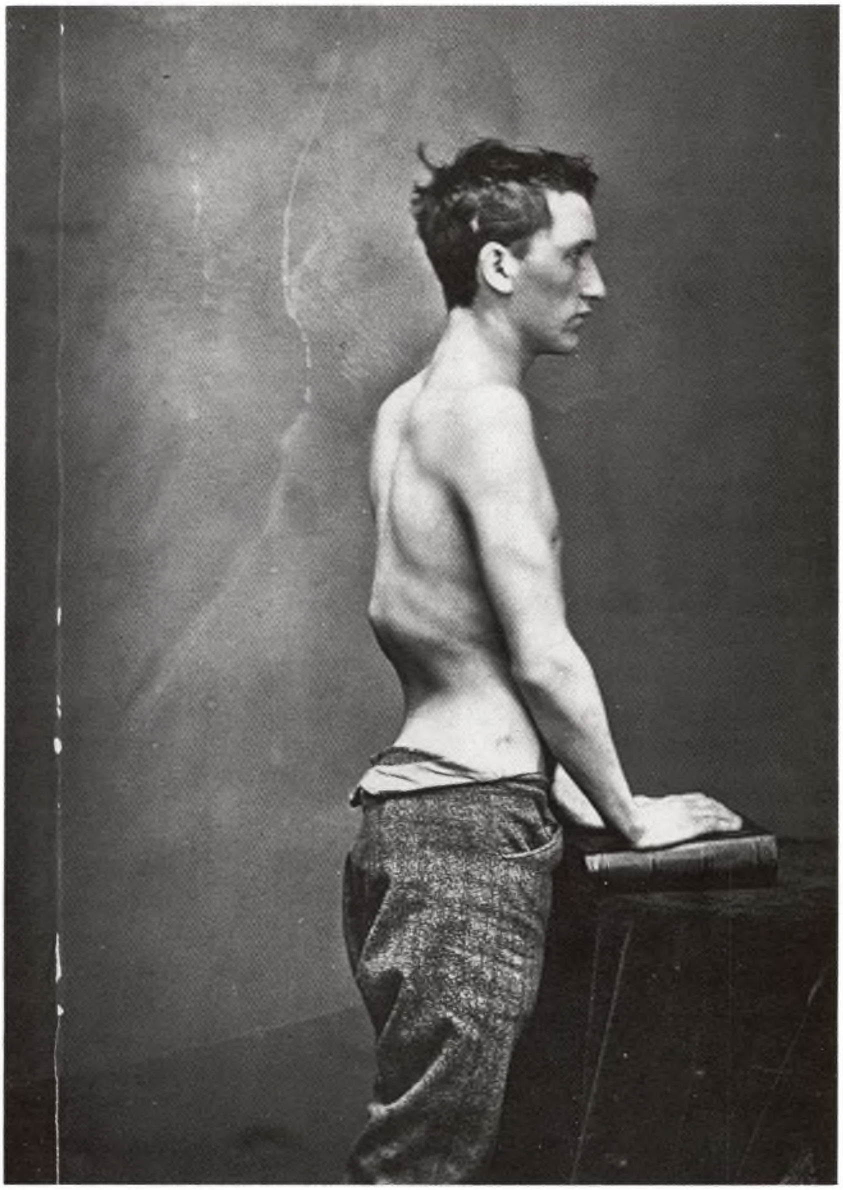
Figure 6.6 The Robert Jones frame, which could be used either for tuberculosis of the spine or hip. From G. R. Girdlestone, *Tuberculosis of Bone and Joint* (London: Oxford University Press, 1940),

was a forceful, logical and picturesque speaker — a genius and also, as you know, a poet.[33]

In the United States patients with spinal tuberculosis usually were treated lying in the supine position on simple frames made of iron pipe and covered with canvas. Such Bradford frames were a basic part of the equipment of all children's hospitals.[34] In Great Britain, the Robert Jones frame was preferred[35] (figure 6.6). While attached to the frames, patients could be moved from bed to litter easily and either end of the body could be raised or lowered as desired. Some patients were treated in the prone position and encouraged to extend the back to limit the progression of the deformity and to develop the extensor muscles of the back. The frames did not interfere with the application of traction and could be bent in such a way that the patient lay in hyperextension in order to prevent or correct deformity (figure 6.7).

Prolonged hospitalization and the provision of specially made apparatus were expensive. For this reason many, if not most, of the children with Pott's disease received incomplete treatment or no treatment at all. What was needed was an inexpensive method of management that would permit the patients to be treated as outpatients. Such a method was developed by Lewis A. Sayre.

Lewis Albert Sayre (1820–1900) was born in New Jersey and after the death of his father was brought up and educated by his uncle in Lexington, Kentucky.[36] After graduating from Transylvania University in Lexington in 1839, he attended the College of Physicians and Surgeons in New York, receiving his medical



Figures 6.8 – 6.10 The treatment of a seventeen-year-old-boy with Pott's disease by suspension and the application of a plaster of paris jacket. 6.8: the initial deformity; 6.9: Sayre (on the left) and his assistant suspending the patient; 6.10: the finished jacket. From Lewis A. Sayre, ***Spinal Disease and Spinal Curvature*** (London: Smith, Elder & Co., 1877), facing p. 87, pl 1.

degree in 1842. He was a prosector in anatomy for a period and in 1853 was appointed as visiting surgeon at Bellevue Hospital. He was very active on the staff and helped to organize the Bellevue Hospital Medical College in 1861. He was then appointed professor of orthopaedic surgery, fractures, and dislocations, the first such position in an American medical school, a post he held until 1898. He was the leading orthopedist of his time and was active in civic and national affairs, being the first and only orthopedist to be elected president of the American Medical Association in 1880.

Sayre described his initial experience with the application of a plaster jacket in a patient with Pott's disease as follows:

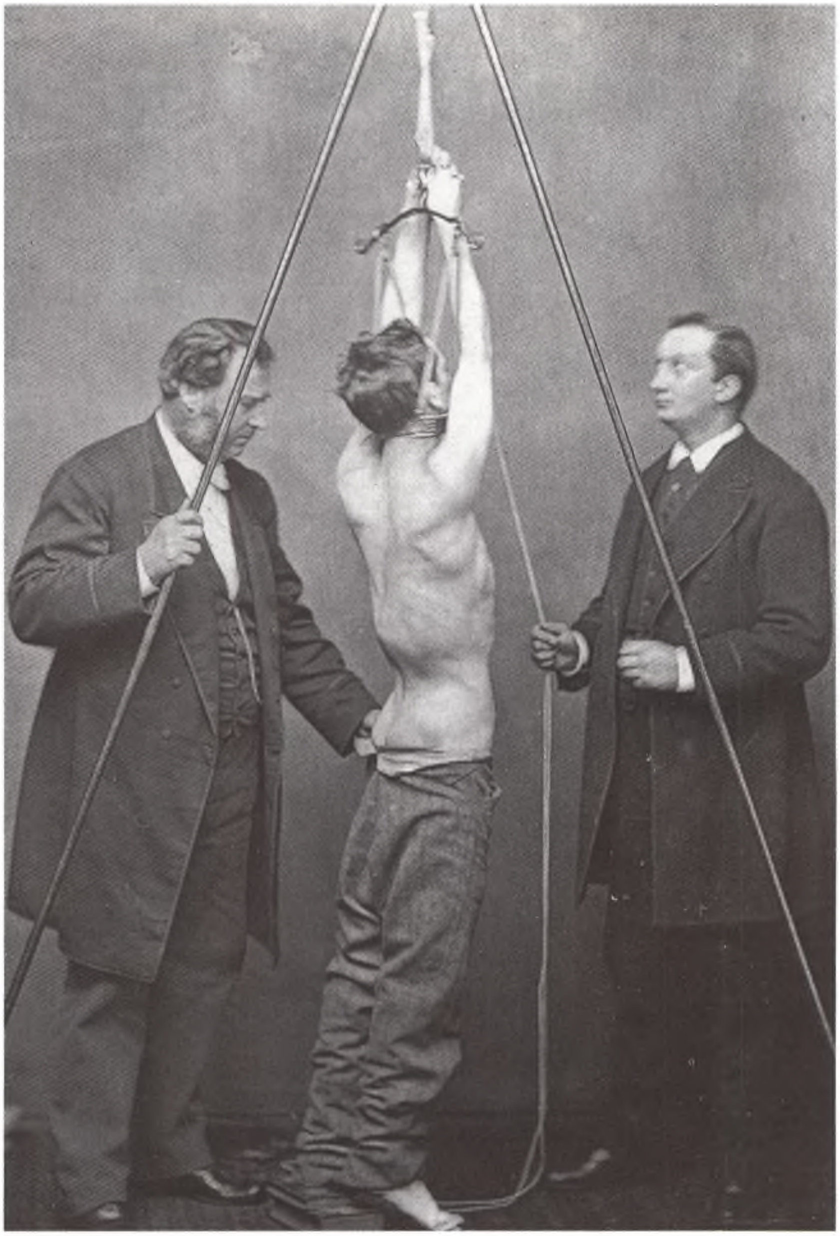


Figure 6.9

In November, 1874, a little boy was brought to me having a sharp posterior curvature of the last three dorsal and first lumbar vertebrae, and there was also partial paralysis of the rectum and one leg. The parents were too poor to buy a brace; it was impossible to send the child to the hospital, so I felt compelled to devise some plan by means of which the boy could be made comfortable while being transported to his home at Chatham Four Corners, Putnam County, N. Y., nearly one hundred and fifty miles distant. Having studied the subject for some time, and questioned myself regarding the propriety of completely encasing the trunk with the plaster dressing, I had finally resolved to make the experiment as soon as a suitable opportunity was offered. It seemed to me that the opportunity had then come, and that the circumstances

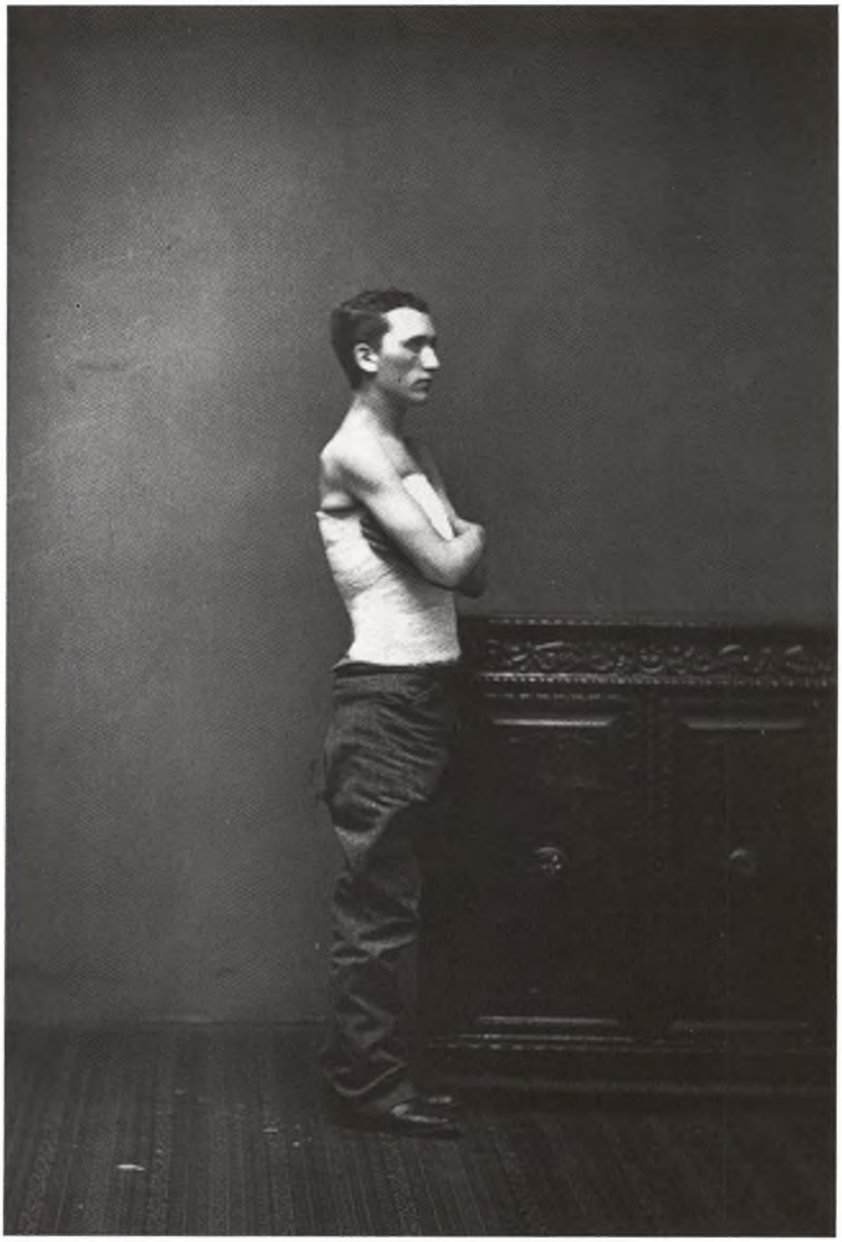


Figure 6.10

justified the measure. Accordingly I directed one of my assistants to suspend the boy by the arms in order to see what effect would be produced, and I noticed that, as soon as the body was made pendent, there was more motion in the paralyzed limb than before, that the pain was very much relieved, and that the patient was breathing much easier. While he was suspended in this manner, I pulled down his shirt and tied it between his legs, thus making it fit the body closely and smoothly, and then took some plaster of Paris bandages which had been prepared in the ordinary manner to be used in the treatment of diseased ankle-joints, and, commencing at the pelvis between the trochanters and the ilium, completely encircled the entire trunk to the axilla. At first I was anxious concerning the effect that would be pro-

Figures 6.11 – 6.12 This-ten-year-old daughter of a physician was treated by Sayre with a plaster of paris jacket incorporating a suspension device. 6.11: the midthoracic gibbus and associated chest deformity; 6.12: the jacket with its "mast" for the support of the head. From Sayre, *Spinal Disease*, facing pp. 82 and 86.

duced upon the respiration, but inasmuch as the boy cried lustily all my fears in that direction were quickly dispelled, and I went on, reversed the bandage, brought it back to the pelvis and so went on until four or five thicknesses of the roller were made to completely embrace the body. He was then laid upon his face on a sofa, and was to remain there until the plaster had become firmly set. I left him on the sofa and went to my lunch, and when I returned I found to my complete astonishment, that the little fellow had got up and walked across the office, and was then looking out of the window.[37]

Figure 6.12

This is but a small extract of a comprehensive, illustrated report of twenty-two cases, which is followed by a lively discussion. Sayre improved and popularized his method and it became widely used throughout the world (figures 6.8–6.12).

Sayre did not accept the idea that there was a relationship between Pott's disease and tuberculosis.

With regard to Pott's disease, I have held for many years that it is, almost if not always, produced through some injury to the bone or cartilage, and that, in common with carious diseases of other joints, it is essentially of traumatic origin. . . .

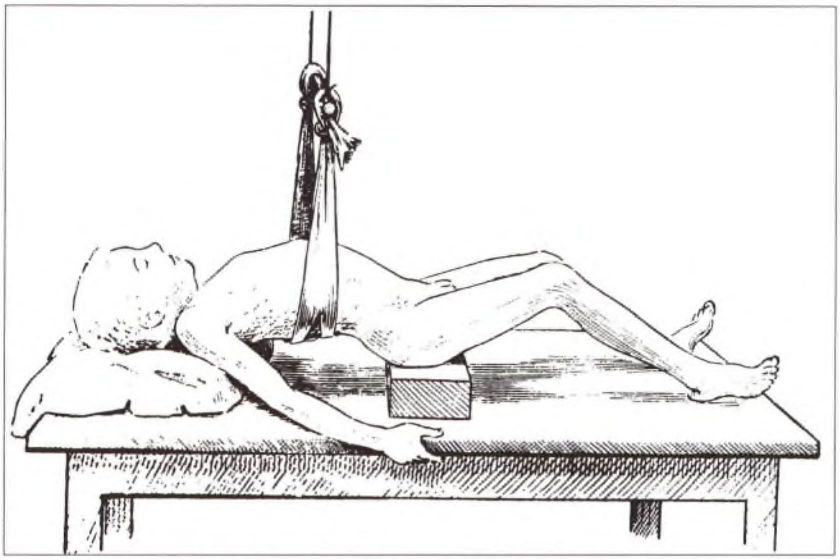


Figure 6.13 Bradford's method of correcting the deformity in Pott's disease while applying a plaster of paris jacket. From Edward H. Bradford and Robert W. Lovett, *Treatise on Orthopedic Surgery*, 2d ed. (New York: William Wood & Co., 1909), 50, fig. 53.

I reject altogether the view held by the profession in general, that Pott's disease is above all others one of essentially strumous origin, that it is necessarily dependent upon a tuberculous diathesis, and never met with save when constitutional dyscrasia is present.[38]

Although Sayre's method produced some correction of the gibbus deformity, suspension was not the most effective manner to accomplish this. E. H. Bradford employed a sling that passed under the apex of the deformity, and with the patient thus suspended, a plaster jacket was applied (figure 6.13). Joel Ernest Goldthwaite (1866–1961) designed a support system utilizing direct pressure over the gibbus while the jacket was applied (figure 6.14). An even more severe technique utilized the *kyphotone* of R. Tunstall Taylor, which combined hyperextension with traction[39] (figure 6.15). These methods were all carried out without anesthesia and the degree of correction of the deformity depended to some extent upon the pain tolerance of the patient. F. Calot utilized a plaster of paris body jacket that was windowed posteriorly over the gibbus.[40] Pressure was applied to the gibbus by means of pads inserted through the window. These pads were changed regularly to maintain the pressure. The results of the methods used to prevent the progress of deformity and to correct it could be very successful (figures 6.16 – 6.17). This was due, to a large extent, to the rapid growth of the small patients and the development of compensatory curves above and below the area of the spine affected.

All sorts of spinal braces and corsets were used in the treatment of patients with Pott's disease, both as a primary treatment or secondarily after the patients plaster jackets were removed. In the United States the most widely used brace, indeed the generic

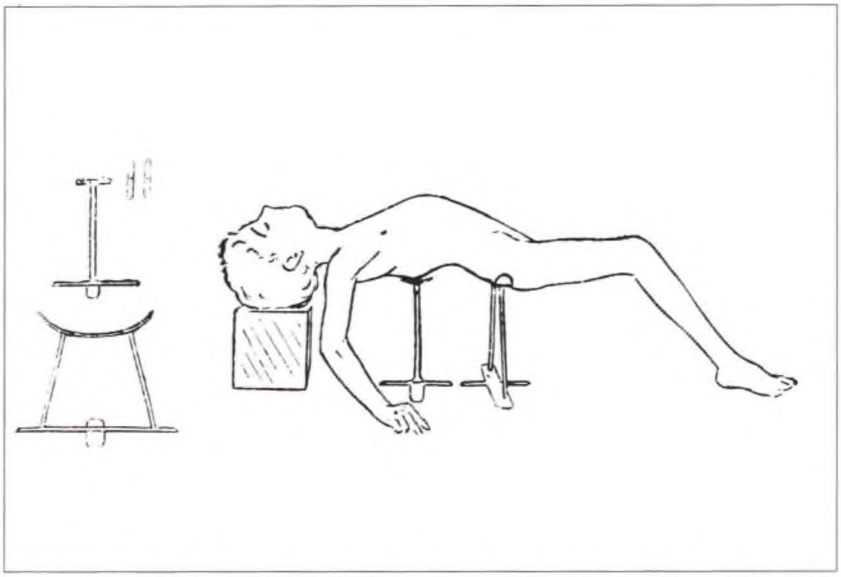


Figure 6.14 Goldthwaite's method of correcting the gibbus while applying the plaster of paris jacket. From Tubby, *Deformities*, 2:169.

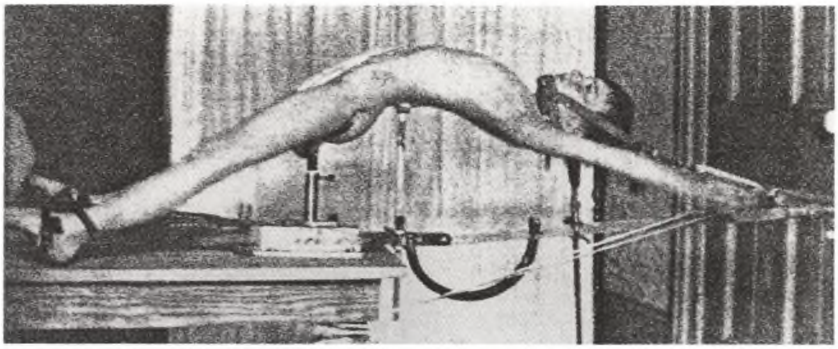
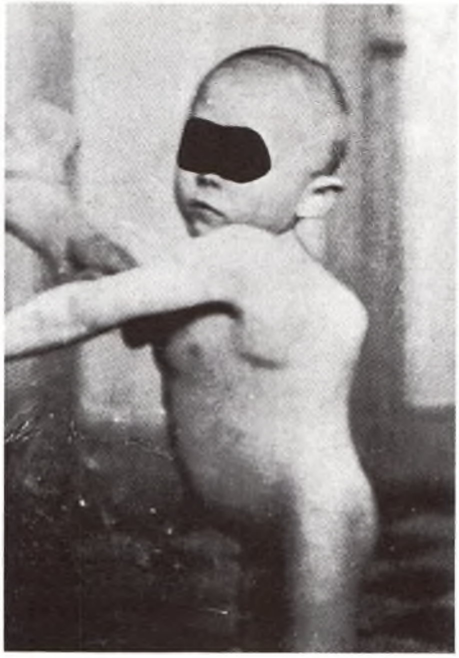


Figure 6.15 The *kyphotone* of R. Tunstall Taylor, which combined longitudinal traction and local pressure over the gibbus to reduce the deformity prior to applying the plaster of paris jacket. From R. Tunstall Taylor, "Hyperextension as an Essential in the Correction of the Deformity of Pott's Disease," *Johns Hopkins Hosp Bull* 12(1901): 32–38, fig. 11.



Figures 6.16 – 6.17 One of Calot's patients before (top) at age 4 years, and after treatment (bottom) at age 12 years, showing the final deformity. From F. Calot, *Indispensable Orthopaedics* (London: Bailliere, Tindall & Cox, 1914), 259–60.

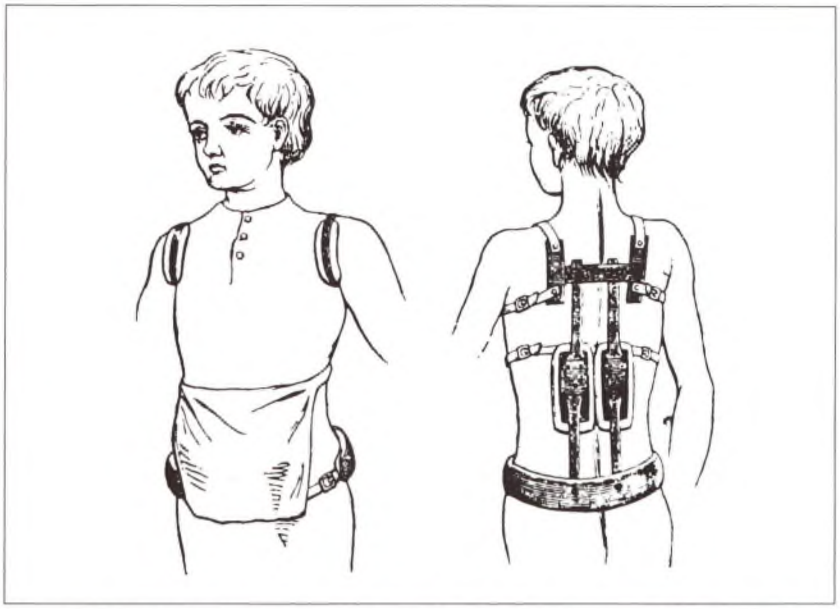


Figure 6.18 Taylor's "spinal assistant." From Alfred R. Shands, Jr., "Charles Fayette Taylor and His Times," *SGO* 143(1976): 814, fig. 3.

model of almost all spinal braces, was the "spinal assistant" devised by Charles Fayette Taylor (1827–1899). In autobiographical reminiscences dictated to his daughter in 1887, Taylor gives an intimate glimpse into the experiences and thought processes over a period of years that resulted in the development of the final design[41] (figure 6.18). The brace itself was only a part of Taylor's treatment. He was successful in his treatment because he carefully supervised every aspect of his patient's care.

The disease known as "Pott's Disease of the Spine" is of so frequent occurrence, that it is remarkable that there has been so little advance made toward its successful treatment, since the time when Dr. Percivall Pott first drew the attention of the profession to its pathology; and though a disease so common that we see the deformity which it produces almost every time we enter an assembly or go into the streets, yet I have observed that these cases are too apt to be avoided by the general practitioner; the physician contenting himself by sending the patient to an instrument maker, for one of the many apparatuses to be found in the shops, and too often leaving the whole matter of kind, form, and fit to the selection of the mechanic.

Now this transferring of responsibility from one's own shoulders to the blacksmith might be well enough, if this person were a pathologist and anatomist as well as a mechanic, but as unfortunately that is never the case, the only alternative would seem to be for the doctor to control the mechanical part of the treatment himself. The mechanic may assist the surgeon as the nurse does the physician, but the one should never take the other's proper place. This would seem to be the more necessary since no two cases are mechanically alike, and no instrument, no matter how well adapted to one case, will necessarily

Figure 6.19 Charles Fayette Taylor (1827–1899) From Shands, "Charles Fayette Taylor," 812.

be proper for another. Simply to apply an instrument, even a good one, is not enough; it should have a definite object and be mechanically, anatomically and physiologically adapted to each particular case; if it fail in any of these it will be ineffectual.[42]

Hugh Owen Thomas was in complete agreement with Taylor on this point, but he solved his problem by becoming his own blacksmith and fabricating all of his braces in his clinic.

Taylor (figure 6.19) was born on a farm in Vermont, the descendant of an old New England family.[43] He did not begin the study of medicine until he was twenty-eight years old, but then progressed rapidly, receiving his medical degree from the University of Vermont in 1856. The following year he went to London, where he studied the Swedish system of therapeutic exercises devised by Per Henrik Ling (1776–1839). This experience led to his publication of a book on the subject.[44] He was very conservative with his indications for surgery, and this, coupled with his interest in what is now thought of as a part of physiatrics and his genius for the design of apparatus for the treatment of orthopedic conditions made him the chief apostle of the "strap-and-buckle" school of orthopedics. He was instrumental in the foundation of the New York Orthopaedic Dispensary, the second orthopedic institution in New York City, which grew to become the New York Orthopaedic Hospital.

One important complication of spinal tuberculosis was the development of what was known as the *cold abscess.*

The tubercular abscess is called a cold abscess because it lacks the characteristic clinical phenomena which attend the development of an acute or hot abscess. There is little, if any, rise of the local temperature, and, unless the abscess has reached the skin, the surface looks rather preternaturally pale than red, and the abscess itself is always painless, and not tender to pressure. The pain, if present, is referred to the primary seat of the tubercular inflammation. Fluctuation is usually well marked, as the tissues around the abscess are not much infiltrated. The most important clinical feature of a cold abscess is its tendency to migrate from the place where it originated to distant localities by gravitation: hence the name given to it by German writers, Senkungsabscess. Thus, in tubercular spondylitis, the abscess may appear in the lumbar region, and is then called lumbar abscess; it may follow the iliac muscle and appear in one of the iliac regions, and is then, from its location, termed iliac abscess; or, finally, it may follow the psoas muscle and appear above or below Poupart's ligament, when it constitutes a psoas abscess.[45]

The spontaneous rupture or surgical drainage of such cold abscesses led to secondary infection and chronic suppuration, often with fatal results. The development of antiseptic-aseptic surgical techniques in the latter part of the nineteenth century did not eliminate this risk. 127 years after David had described this com-

Figure 6.20 The visualization of a chronic draining fistula communicating with a spinal abscess. The image was obtained by using bismuth paste. From Emil G. Beck, *Bismuth Paste in Chronic Suppurations* (St. Louis: C. V. Mosby Co., 1919), 30.

plication, we find another French surgeon, Jean-François Calot (1861–1944) phrasing it this way: "In closed tuberculosis, that is to say without fistulae, healing is certain; opening the tuberculous abscess, or allowing it to open, is to open a portal through which death can enter."[46]

To reduce the danger of spontaneous rupture and to speed up the resolution of the abscesses, their contents were removed by aspiration under very strict precautions and various medications were injected into them.[47] When the contents of the abscess were too thick to permit aspiration, various modifying solutions were injected to promote liquefaction of the caseous material. Among the medications used in different combinations were oil, creosote, iodoform, naphthol, camphor, and glycerine. Iodoform, which had been introduced by Johann Mikulicz (1850–1905) in 1881 for the treatment of infected wounds, became a favorite medication, although complications from iodine intoxication occasionally occurred.[48] When there was a sinus tract, it could also be irrigated and injected with iodoform. One of the more successful techniques was the result of a search for an X-ray contrast material by Carl Beck of Chicago.

> *One of the most difficult problems in this connection seemed to me the question of how to make bone lesions distinct in the* [X-ray] *picture, and particularly how to follow those suppurative conditions to the focus of their origin. When I learned of the favorable results obtained by the use of bismuth in the stomach diagnosis, I immediately thought of the possibility of using it to outline the fistulous tracts and to follow them up to their origin. It took some experimenting before we found the right kind of vehicle which would allow liquifaction* [sic] *and then become solid in the tract, and which would enter into the smallest crevices and at the same time permit the substance to come out again. We first tried gelatin, then water, gum arabic, and other materials, but they all proved failures until heated vaseline solved the problem. Our first case gives a beautiful picture* [figure 6.20]. *When the injected mass failed to return, causing us to fear that we had stopped up the sinus and possibly infected the medullary canal, we felt great anxiety. When we observed, however, that, instead of fever and sepsis, a drying-up and closure of the sinus followed, we were at first surprised and then we began to experiment systematically in other cases.*[49]

The resulting material, consisting of one third bismuth subnitrate and two thirds vaseline, became known as *Beck's paste* and was widely used in the treatment of chronic sinuses associated with tuberculous or pyogenic infections.[50] It was not long after its introduction that iodoform was added to the formula, and it was known by the acronym *B.I.P* (bismuth-iodoform paste) or following the addition of paraffin, as *B.I.P.P.* (bismuth-iodoform-paraffin paste).[51]

It is not suprising that some surgeons, accustomed to reducing deformities resulting from fractures by vigorous manipulations and mechanical apparatus, attempted to reduce forcibly the gibbus of the tuberculous spine. After all, Hippocrates himself had attempted to do so. "The vertebrae of the spine when contracted into a hump behind from disease, for the most part cannot be remedied, more especially when the gibbosity is above the attachment of the diaphragm to the spine."[52] Hippocrates goes on to describes correction of the deformity by succussion and by direct pressure.

But the physicians, or some person who is strong, and not uninstructed, should apply the palm of one hand to the hump, and then, having laid the other hand upon the former, he should make pressure, attending whether this force should be applied directly downward, or toward the head, or toward the hips. This method of applying force is particularly safe; and it is also safe for a person to sit upon the hump while extension is made, and raising himself up, to let himself fall again upon the patient. And there is nothing to prevent a person from placing a foot on the hump, and supporting his weight on it, and making gentle pressure; one of the men who is practiced in the palestra would be a proper person for doing this in a suitable manner. But the most powerful of the mechanical means is this: if the hole in the wall, or in the piece of wood fastened into the ground be made as much below the man's back as may be judged proper, and if a board, made of lime-tree, or any other wood, and not too narrow, be put into the hole, then a rag, folded several times or a small leather cushion, should be laid on the hump; nothing large, however, should be laid on the back, but just as much as may prevent the board from giving unnecessary pain by it hardness; but the hump should be as much as possible on a line with the hole made in the wall, so that the board introduced into it may make pressure more especially at that spot. When matters are thus adjusted, one person, or two if necessary, must press down the end of the board, whilst others at the same time make extension and counter-extension along the body, as formerly described (figure 6.21).[53]

In 1896 the method of forcible correction of the deformity of Pott's disease was revived by Calot (figure 6.22). In August 1897 at the 12ᵉ Congrès International de Médicine de Moscou, Calot gave a practical demonstration as well as a long discussion of his method and the results.[54] Beginning by emphasizing his dedication to conservative methods in the treatment of tuberculosis of the bone, he then illustrated his lecture with X-rays of the spine that showed bony healing in the diseased area after redressment. The results in 204 cases had been generally good. He believed that the method was perfectly innocuous. It consisted of the application of traction to the upper and lower extremities of a force between twenty and eighty kilos, depending upon the age of the

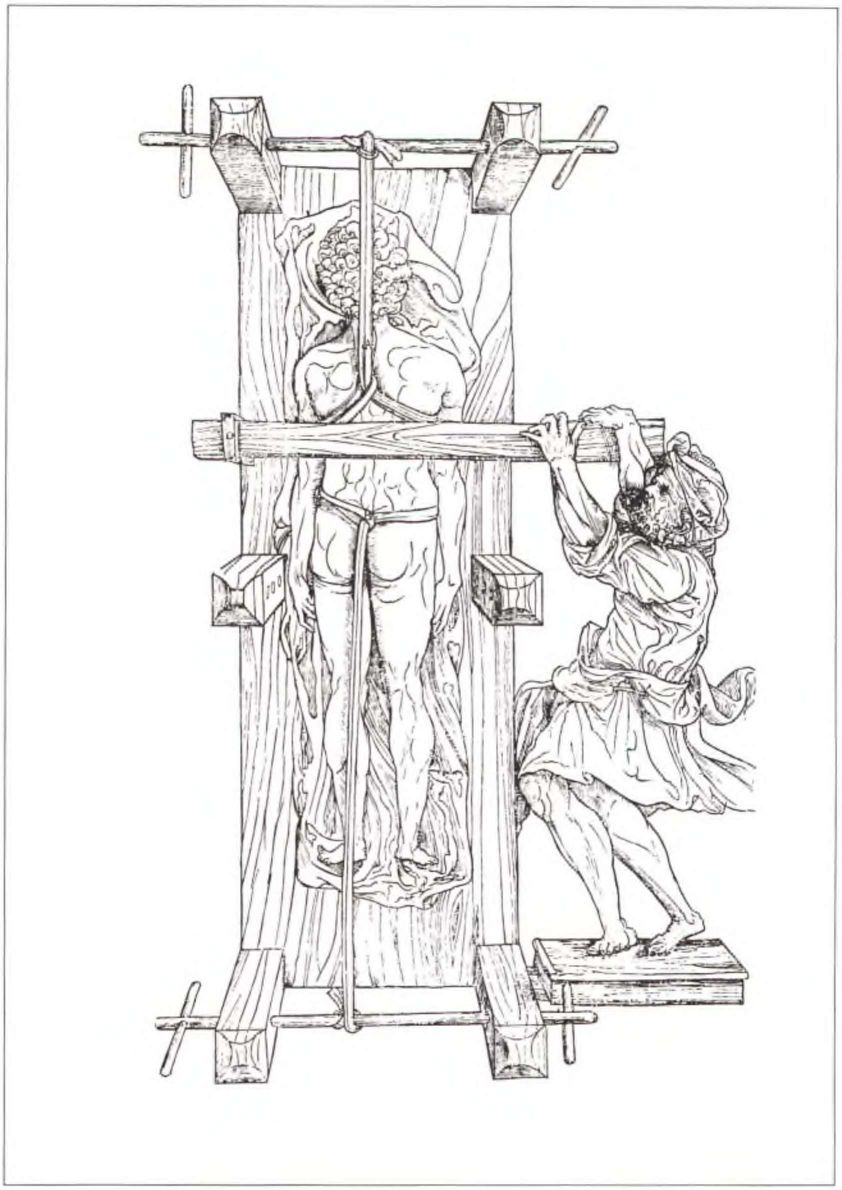


Figure 6.21 Hippocrates' method of forcibly reducing a gibbus. From Guido Guidi, *Chirurgia e graeco latinum conversa* (Paris: Petrus Galterius, 1544), 552.

Figure 6.22 The *redressment forcé* as practiced by Calot. From Bradford and Lovett, *Treatise on Orthopedic Surgery*, 2:45.

Figure 6.23 François Calot (1861–1944). From Charles W. Goff, *Legg-Calve-Perthes Syndrome* (Springfield, Ill.: Charles C Thomas, Pub., 1954), 25, fig. 7-d. Courtesy of Charles C Thomas, Publisher, Springfield, Illinois.

patient. Manual pressure of thirteen to forty kilos was then applied to either side of the gibbus. After the reduction the patient was placed in a plaster of paris body jacket. Deformities in the lower thoracic or dorsolumbar area were the most amenable to this type of treatment.[55] Adolf Lorenz (1854–1946) in Vienna immediately condemned the method.[56] Edward Bradford and Robert Lovett presented the results in 610 patients.[57] There were many complications and the long-term results were not as good as anticipated. Calot himself abandoned this method and by 1911 advised "no violent redressment."[58]

François Calot (1861–1944) (figure 6.23) in his role as head of the Hôpital Rothschild, the Hôpital Cazin, the Hôpital du Departement de L'Oise, and the Institut Orthopédique de Berck, all institutions for the treatment of bone and joint tuberculosis located on the north coast of France, had the opportunity to gather an enormous clinical experience. Through his publications, which were numerous and well written, he influenced the treatment of patients with bone and joint tuberculosis throughout the world. In addition to his work on tuberculosis he also made contributions to the treatment of scoliosis. Treatment in recumbency on a frame or a plaster of paris mould remained the method of choice for treatment of patients with Pott's disease. Just prior to World War I, B. Lange of Strasbourg and Julius Finck of Cracow gave a good summary of the results that could be obtained by these methods.[59] It was not until after World War I that this conservative, nonoperative approach to the treatment of tuberculosis of the spine was slowly supplanted by a more aggressive surgical approach that consisted of correction of the deformity followed by spinal fusion utilizing bone grafts.

In 1891, as the result of a competitive examination, Victor Ménard (1854–1934) was appointed to head the Hôpital Maritime de la ville de Paris à Berck, the hospital that the city of Paris maintained for the treatment of bone and joint tuberculosis.[60] This hospital had 1100 beds and with various adjacent hospitals made this seaside resort on the English channel a center for the study of this condition. Ménard taught that it was a great mistake to treat the local deformities and to forget that tuberculosis was a systemic disease. His primary orientation was toward conservative treatment, but he made an important contribution to the surgical treatment of Pott's disease. In 1894 he described three cases of Pott's disease with paraplegia upon which he had operated.[61] The first operation, a laminectomy, did not benefit the patient; the second operation was complicated by opening into an abscess in the spine; the third operation was carefully planned and more extensive. It resulted in evacuation of the abscess and relief of the paraplegia. This operation was the first costotransversectomy.

Along with Ménard, other surgeons had begun thinking of ways to provide immobilization for the tuberculous spine by

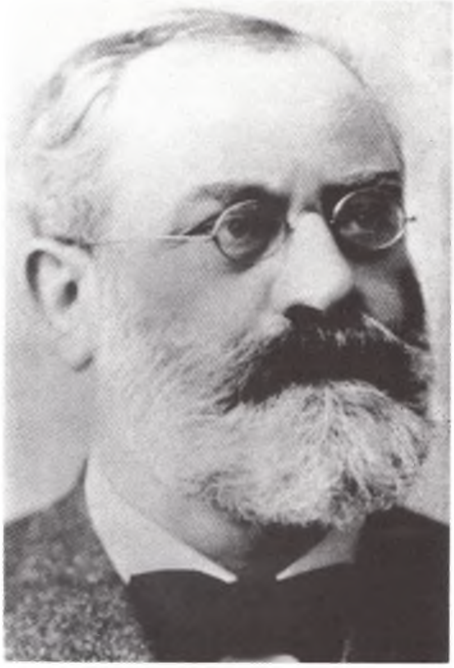


Figure 6.24 Berthold Ernest Hadra (1842–1903). From G. W. N. Eggers, "Berthold Ernest Hadra (1842–1903): A Biography," *Clin Orthop* 21(1961): 33.

Figure 6.25 Antoine Maxime Jules Nicolas Chipault (1866–1920). From D. Petit-Vutalillis, "Anthony Chipault (1866–1920,)" *J Neurosurg* 9(1952): 301.

means of internal fixation. The first of these was Berthold Ernest Hadra (1842–1903) (figure 6.24). Hadra was born and educated in Germany, serving as an assistant surgeon in the Prussian army before emigrating to the United States.[62] He settled in Texas, where he moved frequently from community to community, never staying in one place very long because of personal and professional disappointments. In 1891 he operated upon a thirty-year-old man with an old unstable fracture dislocation of the sixth and seventh cervical vertebrae.[63] He reduced the dislocation and wired the two spinous processes together with silver wire. The operation was repeated three weeks later as the first wires loosened. While his patient did not have tuberculosis, he believed that his operation was applicable to the treatment of patients with Pott's disease and advocated its use for this purpose in a paper read before the American Orthopedic Association in September of 1891.[64]

The first internal fixation of the spine for Pott's disease was carried out in Paris in 1893 by Antoine Chipault (1866–1920) (figure 6.25). Born in Orléans, he moved to Paris for his medical education, showing an early interest in neurology and neurological surgery.[65] Chipault was a gifted linguist and an indefatigable worker. In the short span of eight years, 1894 –1902, he established neurosurgery as a specialty in France. He was particularly interested in surgery of the spinal cord. In 1907 he was incapacitated by the onset of a neurological disease that led to his death in 1920. Chipault was stimulated by some of his colleagues who were discouraged with the difficulties and results of the usual treatment of Pott's disease and attempted to provide a surgical solution to the problem. In 1896 he reported the results of the treatment of five patients with Pott's disease in whom he had carried out stabilization of the spine by means of wiring a number of the spinous processes with silver wire.[66] The spinous processes were exposed through a midline incision over the length of the deformity and the wires were passed through holes in the base of the processes. Some correction of the deformity was obtained at the time of the operation by traction and by direct pressure. The patients were immobilized postoperatively in Bonnet or Taylor braces.

In 1902, stimulated by the ideas of Hadra and Chipault, Fritz Lange (1864–1952) in Munich, after a long series of animal experiments to select a compatible metal, began to stabilize the tuberculous spine by inserting steel rods plated with tin.[67] The rods, which were 0.5 centimeters by 10 centimeters in length, were inserted on either side of the spinous processes and secured in place with sutures passed through the interspinous ligaments. The patient was then placed in a plaster of paris jacket for six weeks, followed by brace support for six months. By 1920, Lange had given up the metal fixation because of corrosion prob-

Figure 6.26 Russell A. Hibbs (1869–1932). From *J Bone Joint Surg* 15(1933): 253.

Figure 6.27 Fred H. Albee (1876–1945). From *J Bone Joint Surg* 27(1945): 345.

lems and had switched to using rods of celluloid, an early plastic material.[68]

In 1912 Russell A. Hibbs (1869–1932) (figure 6.26) described his method of producing a surgical fusion of the posterior segments of the vertebrae, which involved utilizing bone from the spinous processes and the posterior surfaces of the laminae and fusing the posterior facet joints.[69] A meticulous operator, Hibbs was able to produce enough raw bony surfaces and local bone chips to provide a good milieu for fusion. This could be difficult in a small patient because all of the bone used in the fusion came from the area of the operation. Following the operation, the patients were kept in bed for a period of eight to ten weeks and then allowed up with a brace. Hibbs became convinced that this was the way to treat all cases of Pott's disease and he used it in almost every such patient that he saw.[70]

Hibbs was born in Kentucky, attended Vanderbilt University in Nashville, and graduated from the Medical College of the University of Louisville in 1890.[71] In 1894 he became the resident surgeon at the New York Orthopaedic Dispensary and Hospital. Six years later he was made "surgeon and chief." He was also a professor of orthopedic surgery at the College of Physicians and Surgeons at Columbia University. He was known as an excellent teacher and was an important figure in the orthopedic community.

At the same time Hibbs was perfecting his operation, another New York orthopedist was developing his own method. Fred H. Albee (1876–1945) (figure 6.27), like Hibbs, had seen the good results of fusions of the hip and knee for tuberculosis, but he was unable to get enough local bone to fuse the spine in children as Hibbs was able to do. His answer was to employ a bone graft from the tibia, both to supply more bone to the area of the fusion and to provide internal fixation.[72] Albee's technique involved splitting the spinous processes and carefully inlaying a piece of cortical bone from the tibia. He had tried out his procedure on dogs before applying it to patients. His fusion extended over four vertebrae. His postoperative management consisted of one month's rest in bed supine on a Bradford frame, followed by ambulation in a Taylor brace.

Albee was born and raised on a small farm in Maine.[73] He financed his education by working and scholarships, graduating from Bowdoin College, Maine, in 1899 and Harvard Medical School in 1903. He became an intern at the Massachusetts General Hospital. Later on he came into contact with Henry Ling Taylor and Virgil P. Gibney of the Hospital for the Ruptured and Crippled in New York. The greatest influence in his life was his grandfather Charles G. Houdlette, who was a cabinet maker and an expert in the grafting of fruit trees. Working with his grandfather, he learned his lessons well. As an orthopedic surgeon he

Figure 6.28 The anterior bone graft employed by Hirumo Ito. From Hirumo Ito, Junichi Tsuchiya, and Goichi Aszumi, "A New Radical Operation for Pott's Disease," *J Bone Joint Surg* 16(1934): 504.

became a leading proponent of the use of bone grafts and stressed the importance of a precise technique. He believed that pounding upon the bone while using chisels and osteotomes was an important cause of shock in his patients. For this reason he modified an electric saw so that it could be used in the operating room.

The electromotor operating set was devised and introduced by the author some eight years ago; necessity for speed, accuracy, and the elimination of trauma in bone operations was the "mother" of the invention, while the immediate incentives for its production were the inlay bone-graft procedures for fractures, the peg-graft for fracture of the hip, and the spinal graft for Pott's disease, etc. This outfit, with its twin saws and dowel-shapers, introduced for the first time machine work and the automatic tool into surgery, and represents a new departure in that field. It enables the surgeon to perform his work with the greatest nicety and accuracy. The surgeon can thus fashion and fit a dowel peg with as great precision as the artisan who makes and fits a leg to the bottom of a chair by means of his lathe or automatic machine tool.[74]

With his power tools, Albee became the leading proponent of a school of "bone carpenters." In the hands of an experienced surgeon, this rotating electric saw could do exactly what Albee wanted. In the hands of inexperienced surgeons, this high speed rotating saw could be dangerous to the patient as well as to the surgeon and his assistants. Another rotating electric saw designed by J. Vernon Luck (b. 1906) was widely used.[75] Both of these hazardous instruments were quickly displaced by the oscillating saw invented by Homer H. Stryker (1894–1980) in 1945.[76]

The fusion methods of practicing orthopedic surgeons were eclectic and combined the best features of both of Hibb's and Albee's spinal fusion procedures. From Hibbs, they adopted the careful dissection and exposure of the spinous processes and laminae; from Albee, the addition of autogenous bone grafts, not to provide internal fixation, but to increase the fusion mass. This combination has remained the most widely used method for posterior spinal fusion.

The focus of the tuberculous disease in the body of the vertebra was not disturbed by posterior spinal fusion, whose therapeutic value lay in providing immobilization of the diseased segment and promoting healing and ankylosis. A group of Japanese surgeons at Kyoto were not satisfied with this indirect approach and in 1934 published their experience with operations that removed the diseased bone, corrected the deformity, and supported the spine with a graft from the tibia placed anteriorly (figure 6.28). Hiromu Ito (b. 1885) and his colleagues utilized modifications of a retroperitoneal approach for lumbar sympathectomy, an approach for nephrectomy, and costotransversectomy with rib resec-

Figure 6.29 Richard Wiseman (1622–1676). From John Ruhräh, *Pediatrics of the Past* (New York: Paul B. Hoeber, Inc, 1925), facing p. 310.

tion, depending upon the level in the vertebrae, to surgically expose the diseased vertebral bodies. Any local abscesses were treated by aspiration. Initially no graft was implanted, but an Albee type of graft was put in posteriorly several weeks later. This two-stage procedure was abandoned quickly in favor of placing a tibial graft anteriorly at the initial operation. Ito and his colleagues reported satisfactory results in the treatment of ten patients.[77]

After the introduction of chemotherapy, there was a renewed interest in using direct attacks on the diseased vertebral bodies to establish the diagnosis, remove sequestra, and evacuate abscesses.[78] T. Risko and T. Novoszel in Budapest combined an anterior debridement and drainage with a posterior fusion with good results.[79] However, it remained for Arthur Ralph Hodgson of Hong Kong to develop the operation of anterior debridement and fusion to its fullest extent. Beginning with a report of forty-eighty patients in 1956, his experience rapidly increased so that only four years later he could report the results of this operation in 412 patients, with a mortality rate of less than 3 percent.[80] Hodgson was forced to become aggressive in his management of spinal tuberculosis because of the large numbers of seriously ill patients in his clinic and the lack of facilities for long-term conservative management. The combination of conservative management, chemotherapy, and direct attack upon the diseased vertebral bodies gave the orthopedic surgeon the tools he needed to prevent or correct deformity and to promote the healing of the local process.

The terms *scrofula* and *struma* were used for centuries to denote what we now know to be tuberculosis of the lymph glands, a condition commonly associated with tuberculosis of the bones and joints. Scrofula was also called *the King's evil* because it was believed that it could be cured by the touch of the king's hand. From the time of Edward the Confessor (d. 1066) until the beginning of the nineteenth century, the kings of England and France regularly held ceremonies at which they touched patients with scrofula.[81] Richard Wiseman (1622–1676) (figure 6.29), who was Surgeon Ordinary for the Person of Charles II, was required to examine the applicants for cure by his sacred Majesty's touch to make sure that they indeed did have scrofula. The fourth of his eight surgical treatises or books is devoted to a discussion of the King's evil and contains the first good description of tuberculosis of the bones and joints.[82]

The Bones are as frequently affected as any Part of the Body, the Glands only excepted; but there the Manner of the Tumour differs; for though the Bone swell, and the external cortical Part appear hard, yet all within is found putrid and rotten. This Sort of Tumour is sometimes termed Spina Ventosa; but how far that Term is *proper I leave others to judge. This I can affirm, that all the Bones of the Body are subject to this Evil, the Skull itself, and Jaw-Bones not excepted.*

The Bones likewise affected in their Outside by any scrophulous Tumour that happens to touch them, whether in Membrane or Tendon, &c. which we often experience in opening them, when they lie near such Parts: For when we do, we most commonly find the Bone itself bare, if not carious. The Oezaena is often a scrophulous Case.*

As to the Differences of the Strumae; they are sometimes more mild, without Inflammation or Pain, and moderately hard, but by Access of Heat inflame and suppurate; as well those of a round Figure, which is esteemed the best and mildest Sort, as those of any other. Some of the mildest and biggest Strumae, I have seen perfectly suppurated without Change of Colour in the Skin, but after some Days they again become hard as before.[83]

Like the cold abscesses, which lacked the *calor* (heat), these swellings lacked the *rubor* (redness) and were called *white swellings*, that is *tumor albus*, or *tumeurs blanches.*

Wiseman discussed the effects of the process on the bones and joints. He used supportive treatment with good nutrition and a change of air, "the farther removed from the Smoke of the City, the better,"[84] as well as surgical incisions and drainage. He observed that some cases could be cured.

Richard Wiseman was born in London and began his career as a naval surgeon, serving in the Dutch navy for many years.[85] He was a surgeon with the royal forces of Charles I. Having been on the losing side, he had a difficult time establishing a practice in London and left to serve in the Spanish navy. He returned to London shortly before the return of Charles II from exile. Charles II quickly gave him a post as his surgeon and in 1672 he was named "Our principall Chirurgion and our Sergeant-Chirurgion." Wiseman was the leading English surgeon of his day and his volume of eight surgical treatises, including one on the treatment of fractures, show him to have been an experienced and accurate observer.

In 1871, shortly before Koch's discovery of the tubercle bacillus, Theodor Billroth (1829–1894), discussing the fungus and suppurative articular inflammations, defined *tumor albus* as follows:

Tumor albus (white swelling) is an old name which was formerly applied to almost all swellings of the joints that ran their course without redness of the skin; now it has been agreed only to give this name to the affection we are about to describe, which is also, with more or less correctness, termed ***scrofulous inflammation of the joint****; but of this later.*[86]

* *Oezaena*, *ozaena*, or *ozena* was a term used for chronic atrophic rhinitis. The Germans called this term *Stinknase* !

Figure 6.30 The deformity associated with swelling of the hip joint: flexion, adduction, and external rotation associated with apparent lengthening. From A. Bonnet, *Traité des maladies des articulations* (Lyon: Charles Savy Jeune, 1845), atlas pl. 6.

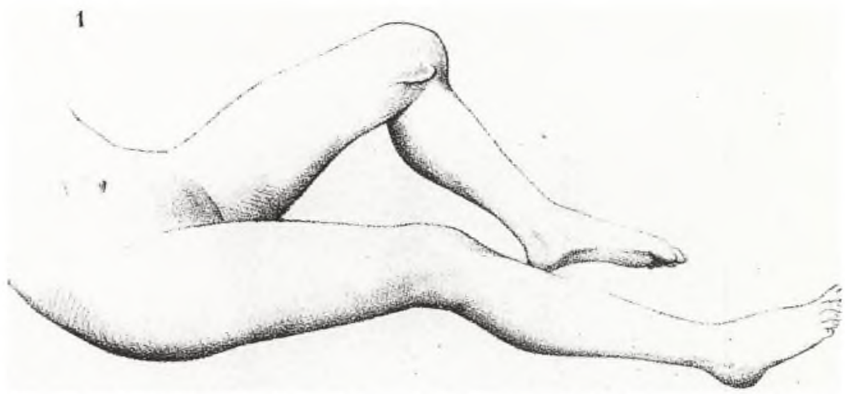


Figure 6.31 The deformity associated with swelling of the knee joint: flexion, external rotation, and posterior subluxation. From Bonnet, *Traité des maladies des articulations*, atlas pl. 5.

Billroth then discussed at considerable length the clinical features, pathology, and treatment of tuberculosis of the bones and joints. Earlier Richard Volkmann had described the evolution of the tuberculous joint infection from its beginning as a small focus in the epiphysis or diaphysis of the bone through the stages of chronic synovitis and destruction of the joint cartilage and the underlying bone.[87]

The general treatment of tuberculosis of the peripheral joints was similar to the treatment of Pott's disease. It depended upon improved nutrition, exposure to fresh air and sunshine, and immobilization. The same institutions that treated the patients with Pott's disease also cared for these patients. Counter irritation as advocated by Pott continued to be used. In 1882 Roswell Park (1852–1914) reviewed the use of the cautery and referred to his method of application as *ignipuncture*.[88] In his technique, the cautery was applied directly to the bone or the joint capsule after exposing it through an incision. He considered the method to be very valuable. Congestive hyperemia produced by the application of venous tourniquets, as advocated by August Bier (1861–1949), was also employed for the treatment of tuberculosis.[89]

One important feature of tuberculosis of the peripheral joints was the consistency of the deformities produced. Each joint tended to assume a characteristic posture as it was affected by the disease. The explanation of this phenomenon was supplied in 1840 by Amédée B. Bonnet (1802–1858) of Lyon, who carried out an extensive series of experiments on fresh cadavers of all ages.[90] By injecting fluids under pressure into the capsules of the joints, he observed that the limbs assumed the positions that permitted the greatest amount of fluid to be injected. He also noted the points of rupture, or the weak spots, in the capsule. He correlated all of his findings with clinical observations on his patients. The hip assumed the position of flexion, adduction, and external rotation; the knee, flexion, posterior subluxation and external rotation of the tibia (figures 6.30–6.31). This beautifully carried out investi-

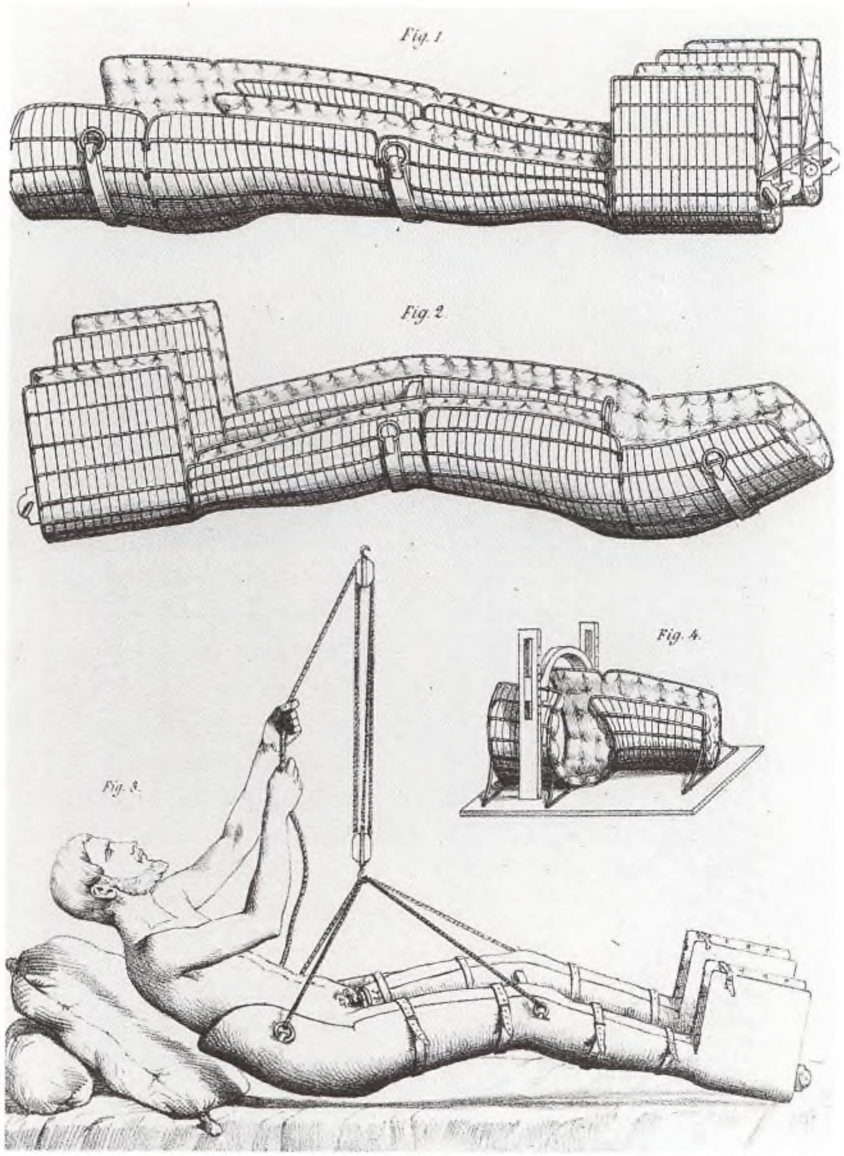


Figure 6.32 The *grand appareil* of Bonnet. From A. Bonnet, *Traité des maladies des articulations*, atlas pl. 15.

gation is well worth reading today as an example of the scientific standard that was achieved in the first half of the nineteenth century.

Bonnet treated his tuberculous patients with fresh air, hydrotherapy, and a good diet. He used a variety of mineral waters and iodine preparations, while locally applying a number of different linaments and poltices incorporating numerous medicaments. He also used chemical cauteries and hot irons and moxae. His splints were made of all sorts of materials, but he is best known for his large padded-wire splints[91] (figure 6.32).

Bonnet's splints did nothing to actively correct the deformity and for this reason other surgeons utilized skin traction with a weight and pulley applied to the lower extremity in order to enforce recumbency and to relieve pain, as well as to correct the

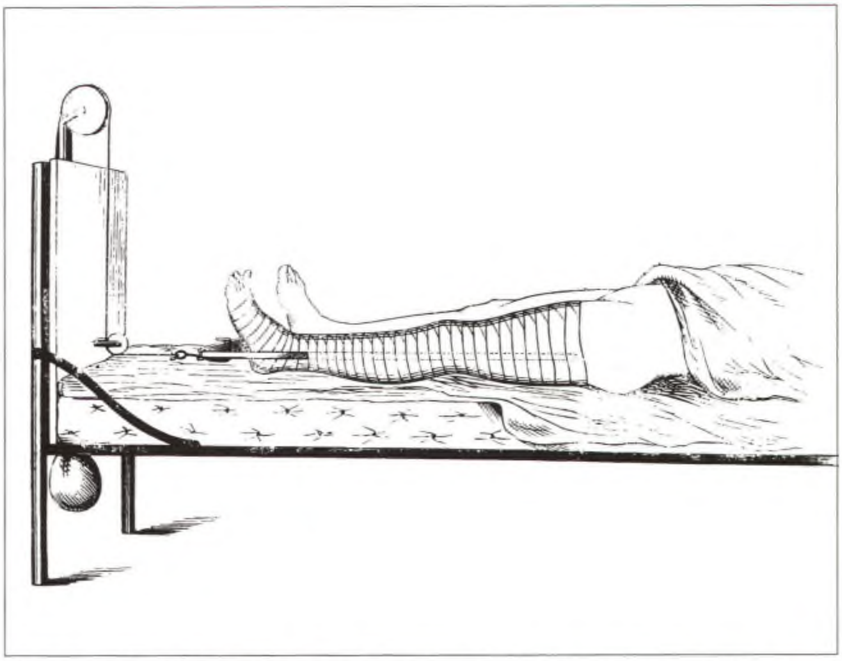


Figure 6.33 Skin traction to enforce recumbency and correct a hip flexion contracture. From Richard Volkmann, "Die Krankheiten der Knochen," in *Handbuch der allgemeinen und speciellen Chirurgie*, ed. Pitha and Billroth (Erlangen: Ferdinand Enke, 1865), 2:745.

deformity (figure 6.33). To utilize the principle of active traction in braces permitting ambulation was more difficult. Henry Gassett Davis (1807–1896) (figure 6.34) accomplished this by exploiting the elastic properties of rubber and developed the so-called "American method of treating joint diseases and deformities."[92] Davis was born in Maine of an old New England family and was educated at Yale University, where he received his medical degree in 1839. After spending fifteen years in Massachusetts as a general practitioner, he moved to New York City and limited his practice to the treatment of diseases of the bones and joints. His success is measured by the fact that he was able to open a small private orthopedic hospital for the care of his many patients. While he maintained his practice in New York City for only fourteen years, retiring to Massachusetts because of ill health, Davis survived for many years.

Figure 6.34 Henry Gassett Davis (1807–1896). From Shands, *The Early Orthopedic Surgeons of America* (St. Louis: C. V. Mosby Co., 1970), 51.

In an article published in 1863, Davis reviews the history of the use of traction and describes the genesis of his ideas.[93] He believed strongly that pressure on the articulating surfaces played an important role in the destructive processes, and that by relieving this pressure, healing was promoted. He also believed that some degree of motion of the diseased joint was desirable.

> *The distinctive principle of my treatment is the procuring to the structures, support without pressure, and motion without friction. The treatment itself, concisely defined, consists in abstraction, of the joint affected, by continuous elastic extension.*[94]

Figure 6.35 Louis Bauer (1814–1898). From Shands, *The Early Orthopedic Surgeons of America*, 16.

Figure 6.36 Hugh Owen Thomas (1834–1891). From H. Winnett Orr, *On the Contributions of Hugh Owen Thomas* (Springfield, Ill.: Charles C Thomas, Pub., 1949), frontispiece.

This extension was accomplished by the use of rubber as the extending power. To carry out his system of treatment he devised a large number of braces, which were used not only for tuberculosis but for clubfeet and other deformities. Davis's brace for tuberculosis of the hip was modified and used by both Sayre and Taylor in New York, Edmund Andrews (1824–1904) in Chicago, and by Volkmann and Friedrich Hessing (1838–1918) in Germany.[95]

The antithesis of motion is immobility, and there were those who believed that allowing even a small amount of motion in the diseased joint was inappropriate. Louis Bauer (1814–1898) (figure 6.35), writing in 1868, stated his position: "*The very first therapeutic axiom* in the treatment of joint disease is *rest, absolute and unconditional*; and the next, *proper position* of the affected articulation." [96]

Bauer was born in Pomerania and educated at several German universities, at one time even studying with Louis Stromeyer in Hanover.[97] He had a taste for controversy with his medical colleagues and for politics. He left Germany after becoming an opponent of Bismark's conservative reformation. Arriving in England, he remained long enough to obtain a wife and a fellowship in the Royal College of Surgeons before moving on to the United States. In Brooklyn he was active in the organization of what became the Long Island College Hospital and Medical School, where he became the professor of anatomy and clinical surgery. A collection of his lectures on orthopedic conditions, published in 1868, was the first textbook on orthopedics printed in the United States.[98] In 1854, with the help of a colleague, Bauer founded the Orthopaedic Institution of Brooklyn, the first such hospital in the New York City area. Unable to get along with his New York counterparts, he moved to St. Louis in 1869, where he again became involved with organizing a medical college and with teaching. All the while he was engaged in polemics with any colleague bold enough to disagree with him. He was the first strong supporter of Hugh Owen Thomas's ideas in the United States and even arranged for Thomas to receive an honorary degree from the University of St. Louis.[99]

The leading proponent of immobilization in the treatment of tuberculous joints in England was Hugh Owen Thomas (1834–1891) of Liverpool[100] (figure 6.36). The son of a professional bonesetter, Thomas and his four brothers were sent to medical school by their father, who realized that they would have better opportunities in the medical profession than as unlicensed practitioners. Thomas built a large practice among the poor in Liverpool, gradually becoming more and more specialized in the treatment of fractures and orthopedic problems. He performed his operations in his own small hospital and fabricated all of his braces and

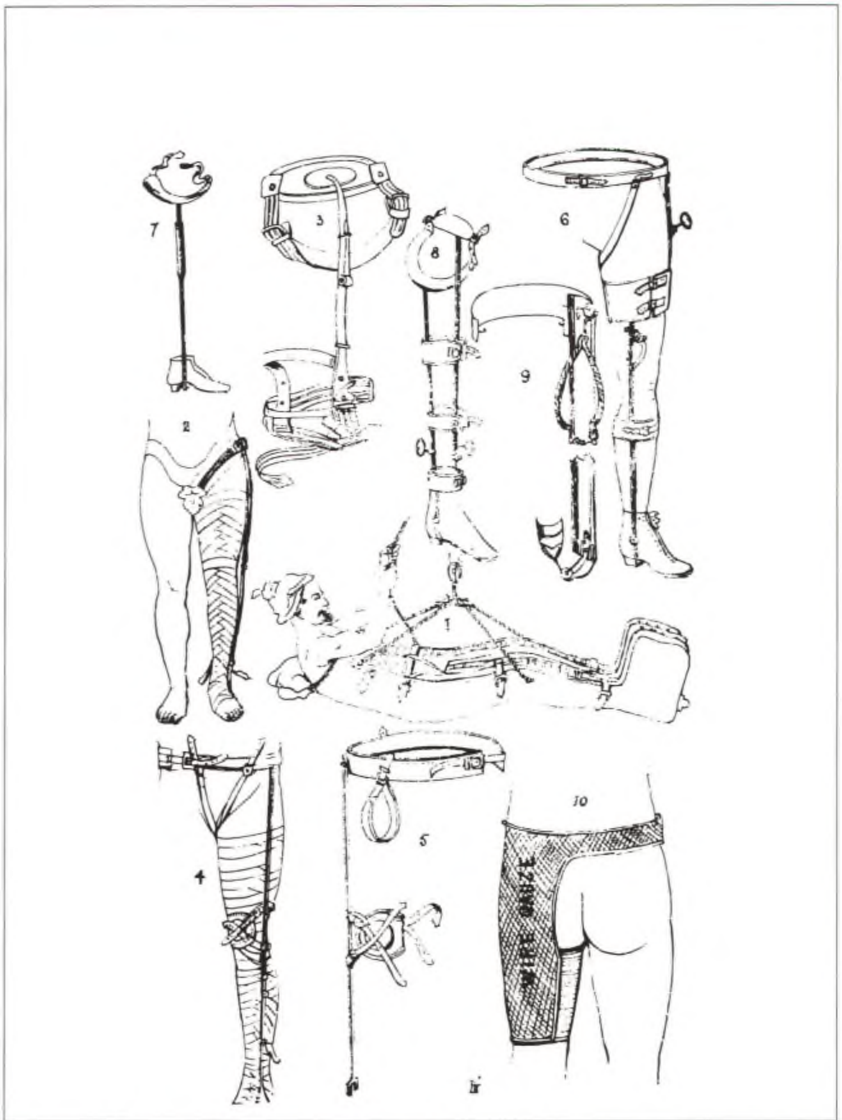
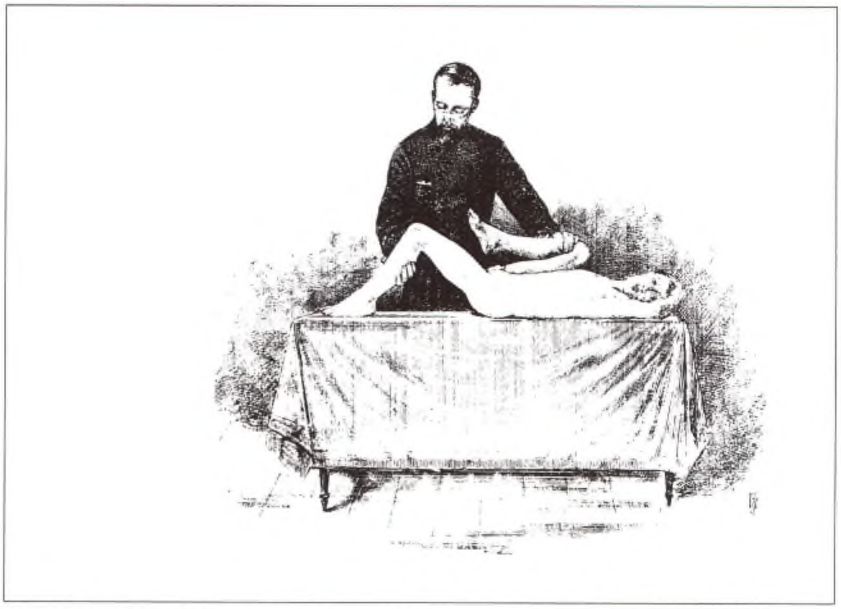


Figure 6.37 This plate illustrates the variety of splints used for the treatment of tuberculosis in the hip and knee: (1) Bonnet, (2) Davis, (3) Sayre, (4) Taylor, (5) Washburn, (6) Hutchinson, (7) Andrews, (8) Bauer, (9) Barwell, and (10) Hamilton. It also demonstrates how well informed Thomas was regarding the practices of his contemporaries. From Thomas, *Diseases of the Hip, Knee and Ankle Joints* (Liverpool: T. Dobb & Co., 1875), pl. 1.

appliances in a shop adjacent to his clinic. He was a well-educated man who published papers in the medical literature of the time and participated in the local medical organizations. Thomas was also a very opinionated man who enjoyed arguing with his orthopedic colleagues. His books did not have a wide circulation because they were distributed poorly by the printer. His book *Diseases of the Hip, Knee, and Ankle Joints,* first published in 1875, gives a good description of his methods of diagnosis and treatment.[101]

Thomas began his book by commenting on many of the braces in use at that time (figure 6.37), and then described the method for determining the presence and degree of hip contracture, now



Figures 6.38 – 6.39 Thomas's test for hip contracture. Top: before flexion of the opposite hip to eliminate the compensatory lordosis; bottom: demonstrating the flexion deformity. From Thomas, *Diseases of the Hip, Knee and Ankle Joints*, pls. 4–5.

Figures 6.40 – 6.41 The Thomas hip splint. Weight-bearing was prevented by means of a patton on the uninvolved side. Top: front view; bottom: rear view. From Thomas, *Diseases of the Hip, Knee and Ankle Joints*, pls. 10–11.

known as the *Thomas test* (figures 6.38 – 6.39). He then illustrated the application of his brace the treatment of hip disease (figures 6.40 – 6.41). It was applied in the position of deformity and adjusted regularly by Thomas himself to slowly reduce the deformity. While no active traction was applied, the joint was not subjected to the pressure of weight-bearing because an elevated shoe was used on the opposite foot. This brace was later adapted by Albert Hoffa (1859–1907) and used in Germany.[102] The brace that resulted from Thomas's invention and Hoffa's modification was hard to apply and maintain unless the patient was under the constant observation of his physician, who managed the adjustments himself. Richard Barwell (1826–1916) of London described some of the problems encountered with this method.[103]

Thomas treated tuberculosis of the knee by means of an ischial weight-bearing splint (figure 6.42). He also used this splint for the treatment of fractures of the shaft of the femur. As a device for first care in the emergency treatment of fractures of the lower extremity, the Thomas splint has been used in military and civilian emergency services throughout the world.

Thomas was fortunate to have as a young associate his wife's nephew, Robert Jones (1857–1933) (figure 6.43), who became one of the major figures in the English-speaking orthopedic world.[104] Jones preserved the legacy of Thomas's ideas and enlarged upon it. Ridlon was a strong advocate for Thomas's ideas in the United States.[105]

Thomas and Jones, and indeed the British school of orthopedics, generally preferred to use braces for immobilization rather than plaster of paris. However, on the Continent and in the United States the use of plaster of paris became popular because of its availability and lower cost. Plaster of paris bandages were used for the immobilization of tuberculous joints immediately after their introduction by A. Mathysen.[106] They were extensively used in Europe and the United States, but not in England, largely due to Thomas's prejudice against them.

The end results in the treatment of tuberculosis of the peripheral joints by these various methods are difficult to determine. While synovial tuberculosis in the very young can heal with recovery of full joint motion, more extensive involvement of the joint can only heal with fibrous or, better yet, bony ankylosis. Prior to the introduction of antibiotics and chemotherapy, the general mortality of the disease was very high. The follow-up of the patients was usually short and incomplete, and objective measurements of joint motion and deformity were almost entirely lacking. James Knight (1810–1887) at the Hospital of the New York Society for the Relief of the Ruptured and Crippled did use a goniometer for the recording of amount of flexion deformity of the hip, a practice that was continued by his successor, Virgil P.

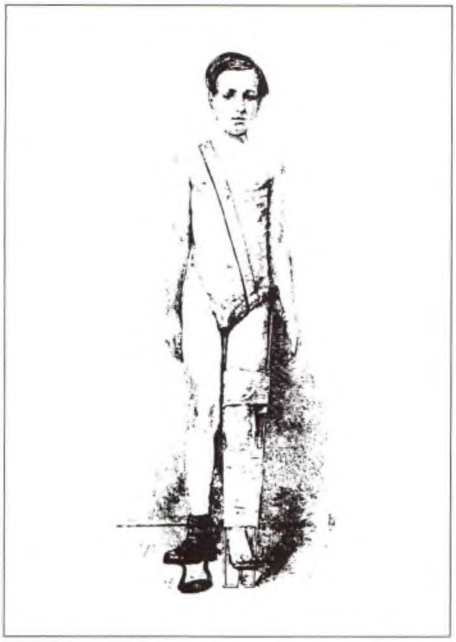


Figure 6.42 The Thomas knee splint. This is the famous "Thomas splint," which, although introduced for the treatment of tuberculosis of the knee, found its greatest use in the treatment of fractures of the femur and as an emergency splint for fractures of the lower extremity. From Thomas, *Diseases of the Hip, Knee and Ankle Joints*, pl. 13.

Figure 6.43 Robert Jones (1855–1933). From Frederick Watson, *The Life of Sir Robert Jones* (London: Hodder and Stoughton, Ltd., 1934), frontispiece.

Gibney (1847–1927), but such measurements were rare.[107] Most authors viewed the results of their methods through rose-colored glasses, and, relying on clinical impressions, were not objective and generally over optimistic. This attitude persisted into the twentieth century. As late as 1940, G. R. Girdlestone maintained that

without a thorough system of follow-up, a "cure" in one hospital register is often a very sick patient in another hospital; a misnomer disastrous for the patient and misleading for the surgeon. Statistics are worthless unless they concern true end-results, ascertained, let us say, at least five years after the patient's discharge form the hospital.[108]

Another source of difficulty was that not all cases categorized as hip disease were tuberculosis. The introduction of the use of X-rays added another dimension to the study of joint diseases, and in 1910 came the description of Legg-Calve-Perthes disease, which in its clinical presentation had many findings in common with tuberculosis.[109] Similarly, when tissue was excised from joints thought to be tuberculous, microscopic examination often failed to support this diagnosis. For example, in a series of 236 patients operated upon for tuberculosis of the knee at the Mayo Clinic in 1933, only 168 were proven to have the disease upon histological examination.[110]

Under favorable conditions, tuberculosis of the joint progressed to either fibrous, or more rarely, bony ankylosis, usually with a disabling deformity. These fixed deformities were frequently subjected to vigorous manipulation, or *brisement forcé*, with or without anesthesia.

When firm adhesions have been formed at the knee joint, correction by means of appliances will be found tedious, painful, and sometimes impossible, and generally forcible correction of some sort will be necessary to break down the adhesions. One way is to break down the adhesions by forcibly flexing the leg, and then by forcible extension to straighten it. The danger of rupturing the popliteal artery, which has occurred, is in this way diminished. Many appliances have been devised to give greater power to forcible correction. One procedure not requiring the use of apparatus is as follows: The patient is placed upon the floor upon the back and the surgeon stands over the patient holding the flexed knee with both hands, the fingers being placed under the popliteal space. The whole weight of the surgeon's trunk can be thrown upon the end of the lever furnished by the patient's leg, the hands of the surgeon, pulling upon the popliteal space, furnishing resistance. After the limb has yielded and the adhesions are broken, it can be straightened if the patient is turned upon the face; a downward force being applied to the heel, resistance being furnished by a cushion placed under the patient's knee. When subluxation of the knee is present it must be corrected.[111]

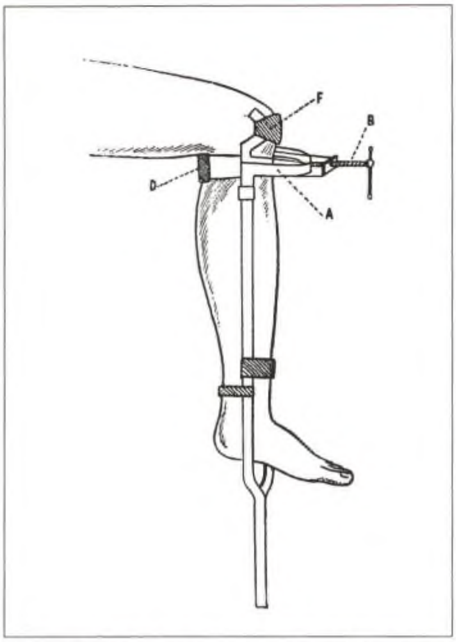


Figure 6.44 The Bradford-Goldthwaite genuclast for the correction of flexion deformity and subluxation at the knee. From Tubby, *Deformities*, 2:302, fig. 191.

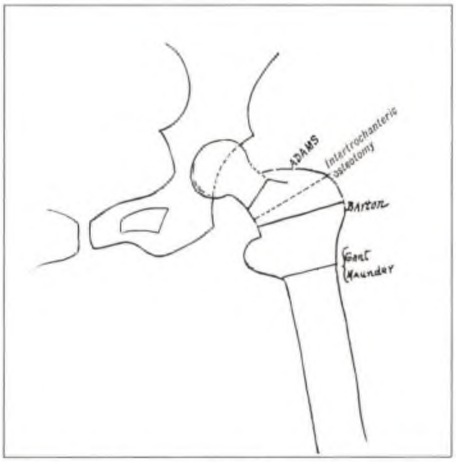


Figure 6.45 Suggested levels for osteotomy of the femur in cases of ankylosis of the hip due to tuberculosis. From Tubby, *Deformities*, 2:273, fig. 165.

Apparatus, such as the genuclast (figure 6.44), devised to apply forces to correct contractures of the various joints when manual efforts failed, resemble the aramentarium used by Torquemada in the Spanish Inquisition. Tenotomy and myotomy were used as adjuncts in some of these procedures. The consequences, such as crushing of the articular surfaces, compression fractures of the metaphyses, stretching of the nerves, and vascular injuries, slowly led to their abandonment. A more successful method of correcting deformities was by the use of osteotomy above or below the joint involved, and if possible beyond the extent of the tuberculous process. A. H. Tubby gives a good account of the use of osteotomy to correct deformity at the hip[112] (figure 6.45).

The direct surgical attack on the tuberculous joints was initiated by Henry Park (1745–1831) (figure 6.46), a student and friend of Percivall Pott. On 18 September 1782, Park addressed a letter to Pott in which he described the case of Hector McCaghen, a thirty-three-year-old sailor with a tuberculous knee. Park excised the lower end of the femur and the upper end of the tibia and brought the ends together. The wound healed and the ends fused together. The patient had a useful limb with three inches of shortening. Park explained the rational of the operation as follows:

> *The resource I mean, is the total extirpation of the Articulation, or the entire removal of the extremities of all the bones which form the joints, with the whole, or as much as possible, of the Capsular Ligament; thereby obtaining a cure by means of Callus, or by uniting the Femur and Tibia, when practiced on the knee; and the Humerus, Radius and Ulna, when at the elbow, into one bone, without any moveable articulation.*[113]

This was the first joint fusion, or *arthrodesis*, to be carried out for tuberculosis.

Park was born and educated in Liverpool.[114] After an apprenticeship with a surgeon in Liverpool, he went to London and studied with Pott, with whom he maintained a lifelong friendship. He had an active surgical and obstetrical practice in Liverpool. Attending the second wife of Sir John Gladstone, he delivered the child who would become the Right Honourable William Ewart Gladstone, who was several times prime minister of England during the reign of Queen Victoria.

Park and the French surgeon, P. F. Moreau, are closely linked in the early development of joint excision for tuberculosis.[115] Their work gave strong impetus to the use of joint excision as a substitute for amputation. It is important to emphasize that by the operation of excision they were seeking to obtain a bony arthrodesis, or at least a fibrous ankylosis, not a pseudoarthrosis. The operation was quickly seized upon by other surgeons as a means of providing useful limbs for their patients. The amount of

Figure 6.46 Henry Park (1745–1831). From D'Arcy Power, "Henry Park, Who Excised Joints in 1781," *Brit J Surg* 24(1936): 206–7.

bone removed varied considerably and, because many of the operations were carried out in children, sometimes included the epiphyses. Large amounts of shortening resulted, which limited the value of the procedure. James Syme (1799–1870) of Edinburgh was the first to caution against removing the epiphyses while carrying out fusion of the knee in children, because this practice would cause excessive shortening.[116] The operation called *excision*, *erasion*, or *fusion*, was in reality an attempted arthrodesis, and became very popular. Large numbers of patients were subjected to it. Because it was often considered an operation of last resort, the mortality rate was very high. Nicholas Senn (1844–1908) gives a thorough account of the experience with these procedures during the latter part of the nineteenth century.[117]

Excision or arthrodesis of the knee was a straightforward technical procedure that corrected the deformity and produced broad flat surfaces of cancellous bone that only needed to be held firmly in place while fusion occurred. Initially surgeons depended on external splinting for immobilization. Ivory pins and bone pegs were used by some surgeons for internal fixation. Later on, tibial bone grafts were used. The use of crossed pins for internal fixation was introduced by Morrant Baker in 1887[118] (figure 6.47). These procedures were not entirely satisfactory because they failed to produce solid bony arthrodesis in a high percentage of cases. Melvin S. Henderson reviewed the experience with knee fusion at the Mayo Clinic in 1915 and concluded that even if the changes on the X-ray were minimal, the operative findings showed substantial destruction of the joint surfaces.[119] This paper was discussed extensively by the leading orthopedic surgeons of the day.

J. Albert Key (1890–1955) of St. Louis was a strong advocate of arthrodesis for tuberculosis of the joints. In 1932, in the introduction to his description of compression arthrodesis of the knee, he stated that he would not

> *discuss the question as to whether or not arthrodesis is advisable in tuberculosis of the knee because it is my opinion that tuberculosis of any large joint is most safely and effectively treated by arthrodesis of the involved joint.*[120]

His operation consisted of excising the ends of the tibia and femur and fixing them by means of large pins passed through the proximal tibia and distal femurs. The pins were then attached together with turnbuckles, which allowed pressure to be applied across to the raw, cut surfaces of the lower end of the femur and the upper end of the tibia, rigidly immobilizing them. He believed the technique to be simple and safe, and that it resulted in more rapid bony ankylosis than other methods. Compression arthrodesis was popularized by John Charnley (1911–1982), who

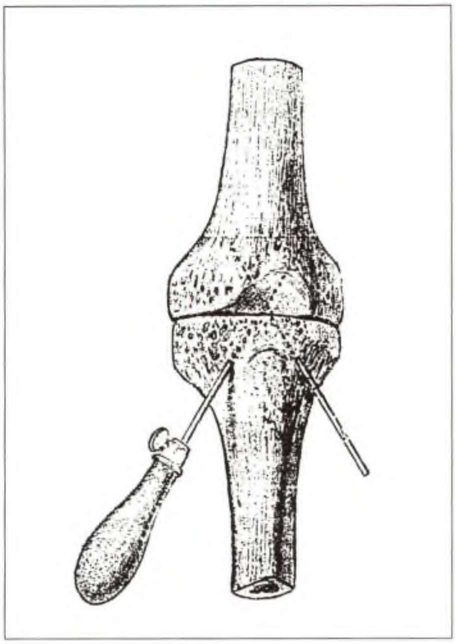


Figure 6.47 Baker's pins for fixation in knee fusion. From Morrant Baker, "A Method of Fixing the Bones in the Operation of Excision of the Knee Joint," *Brit Med J* 1(1887): 321.

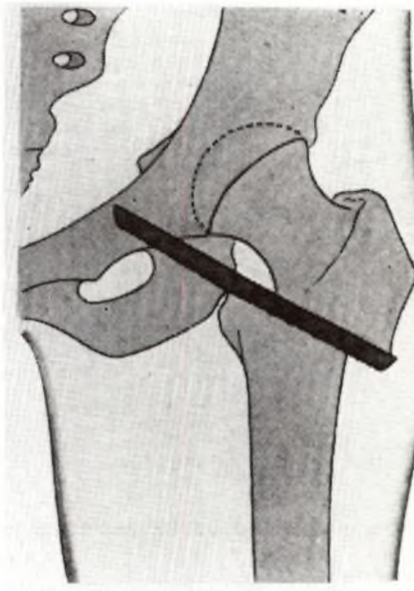


Figure 6.48 Brittain's ischiofemoral fusion utilizing a tibial bone graft to promote fusion and an osteotomy to correct deformity. From H. A. Brittain, *Architectural Principles in Arthrodesis* (Baltimore: Williams and Wilkins Co., 1942), 31.

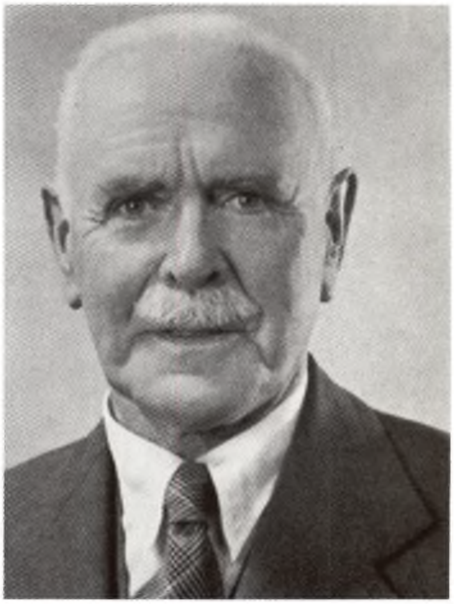


Figure 6.49 Gathorne Robert Girdlestone (1881–1950). From *J Bone Joint Surg* 33B(1951): 130.

extended the technique to include arthrodesis of the shoulder and ankle.[121]

While it was impossible to fuse the knee without entering into the joint, it was possible to avoid disturbing the tuberculous process by an extracapsular operation in the hip, shoulder, and elbow joints. One of the most interesting of these operations was the hip fusion devised by H. A. Brittain, who applied architectural principles to the problem.[122] His operation consisted of a subtrochanteric osteotomy through which a tibial bone graft was inserted into the ischium. The osteotomy allowed correction of the deformity while the bone graft promoted ischiofemoral fusion (figure 6.48).

Operations intended to produce arthrodesis tended to become more sparing of bone as surgeons learned that removal of all of the diseased tissue was unnecessary for success. Excision of too much bone led to the formation of a pseudoarthrosis, which in the knee and ankle joints was a disaster. However, excision resulting in a pseudoarthrosis could give a good functional result as evidenced by the three cases of excision of the elbow reported by Syme in 1829.[123] Extensive tuberculosis of the hip joint, which was not amenable to fusion, could also be treated by radical excision with a functioning pseudoarthrosis. The leading proponent of this operation was Gathorne Robert Girdlestone (1881–1950) (figure 6.49), who described the development of the concept of the operation in his book *Tuberculosis of Bone and Joint.*[124] This text, published in 1940, is the best summary of the surgical treatment of osseous tuberculosis prior to the introduction of antibiotics and chemotherapy. Girdlestone also utilized resection to treat suppurative infections of the hip and even osteoarthritis.[125] This operation is now used as a salvage operation following failed infected total hip arthroplasty.

Girdlestone was born and educated in Oxford, where his father was the first principal of Wycliffe Hall.[126] After obtaining his medical training at St. Thomas's Hospital, London, he went into general practice in Oswestry, Shropshire, the site of what is now called the Robert Jones and Agnes Hunt Orthopaedic Hospital. Contact with these strong personalities led to his career in orthopedic surgery. During World War I, Girdlestone directed the orthopedic division of an army hospital at Oxford. After the war, this hospital evolved into the Wingfield-Morris Orthopaedic Hospital. His friendship with Sir William Morris, Lord Nuffield, resulted in the establishment of the first endowed chair of orthopedics in Britain, to which Girdlestone was appointed in 1937. He used this position to develop the complex system for the care of the crippled and injured in the Oxford region, the Nuffield Orthopaedic Centre, a model for other hospitals of its kind.

In their surgical approaches to the treatment of bone and joint tuberculosis, surgeons frequently encountered cavities in the bone while cleaning out the diseased tissues. These cavities were filled with bone chips dusted with iodoform, Mosetig-Moorhof paste (a mixture of iodoform, spermaceti, and sesame oil), and even plaster of paris.[127] With the X-ray allowing early diagnosis and accurate localization of the defects, Phillipp J. Erlacher (1886–1980) advocated prompt local excision of the early nidus of tuberculosis before it had spread from the bone to throughout the joint.[128]

A wide variety of agents had been used in an attempt to treat tuberculosis prior to the discovery of streptomycin by Selman A. Waksman (1888–1973) in 1944.[129] His discovery grew out of the observation that although tubercle bacilli could grow in sterile soil, they quickly disappeared in natural soil and natural bodies of water.[130] The discovery of streptomycin was the result of a search among soil microorganisms for antibiotic agents active against Gram negative bacteria and mycobacteria. Streptomycin quickly proved to be helpful in the treatment of bone and joint tuberculosis.[131] The addition of para-aminosalicylic acid and isoniazide to the treatment regimen led to further improvement.[132] As a result, the need for surgical intervention in cases of bone and joint tuberculosis diminished very rapidly. However, the indications and surgical procedures have remained the same.

The control of tuberculosis had an enormous effect on the development of the specialty of orthopedics. For over one hundred years the treatment of this disease in its bony manifestations had monopolized the attention of the leaders of the specialty. Many of the specialized children's hospitals closed or changed their orientation. The doctrine of "rest, absolute, uninterrupted and prolonged," which had been applied not only to tuberculosis but a broad spectrum of other orthopedic illnesses, slowly lost its validity. The lessons learned in the management of these unfortunate patients and the principles established in their care formed an important legacy on which succeeding generations of orthopedic surgeons have drawn.

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CHAPTER SEVEN

Poliomyelitis or Infantile Paralysis

Poliomyelitis is a common, acute viral disease characterized clinically by a brief febrile illness with sore throat, headache and vomiting, and often with stiffness of the neck and back. In many cases a lower motor neuron paralysis developes in the early days of the illness.[1]

It is important to remember that while the proportion of individuals affected in whom permanent paralysis developed was small, it was significant, and it was with this group affected with paralytic polio that orthopedists primarily have contended. Experience with the management of these patients led to development of many basic surgical techniques, such as tendon transfer, arthrodesis, and leg-length equalization procedures.

Poliomyelitis had been present for centuries before it was segregated late in the nineteenth century from a great mass of poorly defined conditions. Michael Underwood (1736–1820) (figure 7.1), a London surgeon who practiced midwifery and wrote a book on diseases of children that went through at least twenty-five editions, is credited with the first description of poliomyelitis. What little we know of his education and career has been gathered by W. J. Maloney.[2] In the second edition of his *Treatise on Diseases of Children*, published in 1789, Underwood gives the following account:

The disorder intended here is not noticed by any medical writer within the compass of my reading, or is not so described as to acertain the disease. It is not a common disorder, I believe, and seems to occur seldomer in London than in some other parts. Nor am I enough acquainted with it to be fully satisfied, either in regard to the true cause, or seat of the disease, either from my own observation, or that of others; and I have myself never had the opportunity of examining the body of any child who has died of this complaint. I

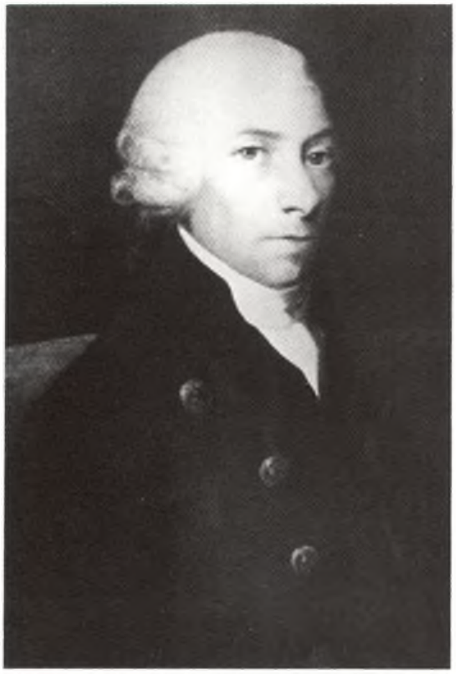

Figure 7.1 Michael Underwood (1736–1820). From W. J. Maloney, "Michael Underwood: A Surgeon Practicing Midwifery from 1764–1784," *J Hist Med Allied Sci* 5(1950), facing p. 289.

shall therefore only describe its symptoms, and mention the several means attempted for its cure, in order to induce other practitioners to pay attention to it.

It seems to arise from debility, and usually attacks children previously reduced by fever; seldom those under one, or more than four or five years old. It is a chronical complaint, and not attended with any affection of the urinary bladder, nor with pain, fever, nor any manifest disease; so that the first thing observed is a debility of the lower extremities, which gradually become more infirm, and after a few weeks are unable to support the body. There are no signs of worms, or other foulness of the bowels; therefore mercurial purges have not been of any use, neither has the bark, nor hot, nor cold-bathing. Blisters, or caustics on the os sacrum, and the great trochanter, and volatile and stimulating applications to the legs and thighs, have been chiefly depended upon; though there is no appearance of enlargement of any of the vertebrae, or joints of the back, nor of suppuration in the external parts, and therefore no resemblance to the inflammation of the intervertebral cartilages, the psoas abscess, or the morbis coxaris of De Haen [tuberculosis].

When only one of the lower extremities has been affected, the above means, in two instances out of five or six, entirely removed the complaint: but when both have been paralytic, nothing has seemed to do any good but irons to the legs, for the support of the limbs, and enabling the patient to walk. At the end of four or five years, some have by this means got better, in proportion as they have acquired general strength: but even some of these have been disposed to fall afterwards into pulmonary consumption, where the debility has not been entirely removed. On this account, it may be suspected that the complaint is sometimes owing to scrofula; and I have been very lately informed by a gentleman of character, that he has seen one instance of a paralysis or debility of this kind, in which, upon opening the body after death, the internal surface of the lower vertebrae lumborum was found to be carious, though there was no abscess of the psoas muscle, nor external tumor on the back, or loins.

I have seen a similar debility seize grown people, especially women, after some very long illness, and has continued a year, or more: during which time they were utterly incapable of walking without the help of crutches. These cases, however, have always been attended with great pain in the commencement of the complaint, though without tumour of the limbs; and have seemed to be benefitted by the external use of the waters at Bath.[3]

Fifteen years later the Italian surgeon Giovanni Batista Monteggia (1762–1814) also noted the condition.

Paragraph 558. In this connection should be mentioned a certain kind of paralysis limited to one or the other of the lower extremities which I have observed several times in practice but have not yet *found in the literature. It occurs in children who are nursing, or not much later; it begins with two or three days of fever, after which one of the extremities is found quite paralyzed, immobile, flabby, hanging down, and no movement is made when the sole of the foot is tickled. The fever ceases very soon, but the member remains immobile and regains with time only an imperfect degree of strength. I knew such a person who even when adult remained dragging a weak leg, for it had not become cured by time.*

Paragraph 559. Likewise it often happens that the disease shows itself simultaneously in both the lower extremities, but this does not last long since in one or two days the paralysis is reduced to one only.

Paragraph 560. I am not very certain as to the cause of this disease, but having observed that it comes with fever, and having recently seen it in a child accompanied by symptoms of dysentery makes me suspect that it comes from colic or rather a rheumatic affection.[4]

Figure 7.2 Jacob Heine (1800–1879). From John R. Paul, *A History of Poliomyelitis* (New Haven: Yale University Press, 1971), 31, fig. 6.

Jacob Heine (1799–1879) (figure 7.2), a member of the distinguished orthopedic family from Würzburg, published a monograph in 1840 that dealt with the treatment of the residual paralysis in patients with poliomyelitis.[5] This was the first monograph that discussed the overall care of the paralytic stage of the disease. A second enlarged edition of this work was published twenty years later.[6] For this reason paralytic poliomyelitis has been given Heine's eponym along with that of Oskar Medin (1874–1928), a Swedish pediatrician who described the condition thoroughly in 1890,[7] and is referred to as Heine-Medin disease.

As early as 1828 J. Abercrombie, a Scottish neurologist, had surmised purely on clinical grounds that the lesion of poliomyelitis was in the anterior portion of the grey matter of the spinal cord.[8] Heine in 1840 and 1860, and Duchenne in 1855, also expressed this view.[9] It remained for J. M. Charcot in 1870 to establish this on the basis of histologic studies on the diseased portion of the spinal cord.[10] The patient had had poliomyelitis at the age of nine. Her residual paralysis was extensive. When she died of tuberculosis at fifteen, a thorough autopsy examination, in addition to documenting her deformities, included an examination of the spinal cord. The localization of the pathological changes in the grey matter of the anterior portion of the spinal cord was responsible for the term *poliomyelitis anterior acuta* formed from the Greek words meaning inflammation (*itis*) of the grey (*polio*) marrow (*myelos*) of the anterior portion of the spinal cord. The introduction of this term is attributed to Adolph Kussmaul (1822–1902).[11] The best correlation between the clinical picture and the pathological findings in the spinal cord can be found in the work of William J. W. Sharrard of Sheffield, who concluded after a very rigorous study of many patients that "the distribution of the paralysis in an individual lower limb is determined by the site and size of foci of motor cell destruction."[12]

Guillaume Benjamin Duchenne listed the following points of importance in the diagnosis of poliomyelitis:

1. *Sudden onset, usually with fever, sometimes without; with or without convulsions.*
2. *Paralysis, at first complete and extensive, gradually diminishing and settling in a greater or lessor number of muscles.*
3. *Diminution of electric contractility from the first in direct proportion to the amount of damage done to the innervation of the paralyzed muscles; after a time return of electric contractility in those muscles or parts of muscles, the tissue of which is not changed.*
4. *Various partial deformities of the limbs in the very advanced stage, resulting from the loss of balance in the tonic muscular power; arrest of the development of the bones in the regions whose innervation is at fault.*
5. *A primary spinal change, demonstrated by analogy and confirmed by pathological anatomy.*[13]

Robert W. Lovett of Boston had this comment:

The attack itself, apart from these characteristics [referring to changes in the spinal fluid], *may resemble an ordinary gastro-intestinal attack, a common cold, influenza, the beginning of one of the exanthemata or other of the common acute affections of childhood. The appearance of tenderness often masks the condition and leads to incorrect diagnosis; it must be remembered that tenderness is a routine symptom in the majority of cases.*

When the paralysis has occurred, the diagnosis as a rule presents but little difficulty. It is a motor paralysis, or weakening of erratic distribution, most marked in the legs. Reflexes are diminished or lost, the reaction of degeneration is present in the most severely paralyzed muscles, atrophy, retarded growth, coldness, and sluggish circulation supervene in the later stages in many cases. Atrophy of the thenar eminence is a frequent occurrence in infantile paralysis and at times throws light on the diagnosis of doubtful cases.

But even when paralysis has developed the diagnosis is not always quite easy. . . .

The history is often misleading and one must at times be prepared to make the diagnosis on the physical signs which are left after the attack without regard to the history. The origin of the paralysis is at times attributed to trauma by the parents.[14]

Treatment of the poliomyelitis patient in the initial stages was generally nonspecific, with the use of cupping or the application

Figure 7.3 A young lady with untreated deformities due to poliomyelitis. From J. F. Dieffenbach, *Ueber die Durchschneidung der Sehnen und Musklen* (Berlin: A. Förstner, 1841), pl. 7.

of blisters along the back or the involved extremities.[15] These gave way later to medications such as calomel or strychnine. The affected muscles were commonly stimulated by the application of both faradic and galvanic currents.[16] Robert Jones emphasized the importance of not overstretching the weakened muscles and the importance of preventing deformities.[17] Failure to do this led to the progression of the deformities due to the muscle imbalance (figure 7.3).

The first important epidemic of poliomyelitis in the United States to be well documented occurred in Vermont in 1894.[18] Patients from this and subsequent epidemics came to the atten-

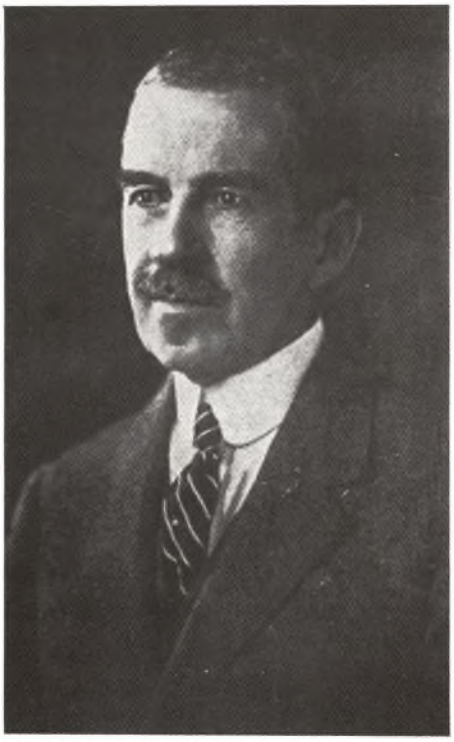

Figure 7.4 Robert W. Lovett (1859–1924). From Robert B. Osgood, *The Evolution of Orthopedic Surgery* (St. Louis: C. V. Mosby Co., 1925), 68, fig. 49.

tion of Robert W. Lovett (1859–1924) (figure 7.4), the John B. and Buckminster Brown Professor of Orthopedics at Harvard University. As chairman of the Harvard Infantile Paralysis Commission, he had ample opportunity to study the disease and its consequences. The second edition of his book on the treatment of poliomyelitis gives the best summary of his work.[19] Lovett also wrote on the subject of scoliosis.[20] He played an important role during World War I in preparing American orthopedic surgeons for their assignments in Europe. It was during this time that he became closely associated with Robert Jones. This led to the joint authorship of a complete textbook of orthopedic surgery.[21] In 1924, while bound for Europe on an ocean liner, Lovett became ill. Upon reaching Liverpool he was taken to the home of his friend Robert Jones, where he died.

In summarizing the treatment of poliomyelitis during the acute phase Lovett concluded:

> *Rest until the tenderness has disappeared, absence of meddlesome therapeutics, either medicinal or physical, the use of warm salt baths in the later part of this period, and possibly the early injection of immune serum. The prevention of contractions.*[22]

In the late stages of the disease he advocated the use of massage, heat, and electrical stimulation.[23] He urged that muscle training be an integral part of rehabilitation and he devoted an entire chapter to this subject.[24] In order to evaluate his patients and the effects of treatment upon them, Lovett also developed a method of measuring the strength of individual muscles and muscle groups.[25] Lovett's work served as guide for the treatment of poliomyelitis for the next twenty-five years.

By the decade of the thirties, Lovett's rather *laissez faire* approach to the treatment of acute poliomyelitis had been supplanted by programs of immediate and extended immobilization of patients, usually by means of plaster of paris splints.[26] While this may have been of benefit in relieving pain, it made careful reevaluation of the state of the muscles difficult and it added an element of disuse atrophy to the affected and unaffected muscles, which further complicated recovery and rehabilitation.

The election in 1932 of President Franklin D. Roosevelt, who had extensive paralysis of both lower extremities as a result of an attack of poliomyelitis in 1920, raised public interest in the condition, which was heightened by epidemics occurring in the United States in the the thirties. Initially funds for research were raised by means of the President's Birthday Ball Commission, an organization that was renamed the National Foundation for Infantile Paralysis in 1938. Since there seemed to have been no progress in the treatment of patients with acute poliomyelitis, the scene was set for the arrival on the world stage of one of the most enigmatic and yet most charismatic figures of the twentieth century.

Figure 7.5 Sister Elizabeth Kenny (1880–1952). From Elizabeth Kenny, *And They Shall Walk* (New York: Dodd Mead & Co., 1945), frontispiece.

Sister Elizabeth Kenny (1880–1952) (figure 7.5), an Australian nurse, acquired her knowledge about poliomyelitis entirely empirically and as a result her ideas about the disease were outside of the mainstream of medical thought. Even her vocabulary and descriptions of her findings were hard for physicians to understand. After gaining acceptance for her ideas and methods in Australia, she arrived in the United States on 14 April 1940 to begin her crusade against poliomyelitis.[27] After facing opposition from physicians in various medical centers, she was given the opportunity to demonstrate her techniques in Minneapolis. Her success made her an international celebrity and she became one of the most widely recognized personalities of the period. Her lasting monument is the Sister Elizabeth Kenny Institute and Foundation in Minneapolis, founded in 1942 and still active as a center for the diagnosis and treatment of neurological diseases.[28]

Sister Kenny was forthright in her condemnation of the immobilization of patients with poliomyelitis during the acute period, giving twelve different reasons for her dissatisfaction, six of which were:

> *1) Immobilization prevents the treatment of the disease, that is, the symptoms of the disease, in the acute stage.*
>
> *2) It prolongs the condition of muscle spasm and prevents its treatment.*
>
> *3) It prevents the treatment for the restoration of coordination of muscle action, a serious error.*
>
> *4) It promotes the condition of stiffness which according to all reports prevents satisfactory treatment either for the symptoms that brought about the condition (muscle spasm) or the development of muscle power by re-education, or the reawakening of impulse.*
>
> *5) It interferes with the nutrition of the skin, subcutaneous tissue and muscles.*
>
> *6) It reduces circulation.*[29]

The Kenny concept of the acute stage of poliomyelitis was based on the recognition of four conditions: (1) muscle spasm; (2) mental alienation of muscle or nerve-muscle dissociation, that is, pain inhibition; (3) incoordination of muscle action; and (4) muscle weakness and paralysis.[30] Her success was based upon the significant degree of pain relief afforded by the use of continuous hot packs, which eliminated paralysis due to pain inhibition, and to the early institution of a continuous program of muscle reeducation and rehabilitation. Her methods of management became established throughout the world and remain the best available today.

The work of Jonas E. Salk (b. 1914) resulted in the development of an inactivated viral vaccine, and that of Albert B. Sabin (b. 1906), of an attenuated live virus vaccine.[31] Since the midpoint of this century, poliomyelitis has been largely eliminated in most developed countries, but it remains a major crippling disease in the third world.

The study of the course of poliomyelitis and especially the evaluation of any form of treatment depended upon accurate methods of measuring the strength of individual muscles and observing changes in strength as time passed. Lovett had attempted to do this by means of the spring balance muscle test, which consisted of a complicated system of measurements carried out by means of a spring balance.[32] This method proved to be too cumbersome in its application to the varied patient population and not well adapted to use in other neurological conditions. What eventually evolved was a much simpler system devised by the Nerve Injuries Committee of the Medical Research Council of Great Britain during World War II.[33] This method could be applied to almost all conditions affecting the peripheral nerves and it could be easily taught to physical therapists and physicians. In experienced hands it had a very high degree of reproducibility and soon was accepted worldwide as the method of choice. The strength of individual muscles were graded on a scale of zero to five: 0 = no contraction, 1 = a flicker or trace of a contraction, 2 = active movement with gravity eliminated, 3 = active movement against gravity, 4 = active movement against gravity and resistance, and 5 = normal power.

There has always been interest in methods of strengthening the weakened muscles by exercise using a variety of methods and equipment (figures 7.6 – 7.9). Another development arising from experience with rehabilitation of the injured in World War II was an improved technique of muscle-strengthening exercises. The method was called progressive resistance exercise (figure 7.10). and was perfected by Thomas L. DeLorme.[34] This method was quickly applied to the rehabilitation of poliomyelitis patients at the Massachusetts General Hospital with the support and financing from the Pope Foundation Inc. of Kankakee, Illinois. Henry Pope, the founder of this organization, had a daughter with poliomyelitis and was interested in hydrotherapy for her. He was a founding member of the Georgia Warm Springs Foundation along with Franklin D. Roosevelt. Pope devised the Hubbard tank as well as the Klenzak ankle, an important brace innovation. He also pioneered the use of mass-produced parts in brace manufacture.[35]

Experience in the management of patients with poliomyelitis revealed that the patients were subject to two unusual complications. The first, heterotopic new bone formation, was a complication associated with a variety of neurologic and other conditions.

Figures 7.6–7.9 7.6: Apparatus for ascertaining minute amount of muscular contractility in flexors or extensors of foot and for developing same; 7.7: Apparatus for developing the flexors or extensors of the leg; 7.8: Apparatus for developing extensors of the leg and to antagonize shortening of flexors; 7.9: Apparatus for developing power of extension of whole-leg walking motion. From Charles F. Taylor, "The Uses and Abuses of Tenotomy in Cases of Muscular Atrophy," *Trans Med Soc NY* (1865): 18–26, pls. 3–6.

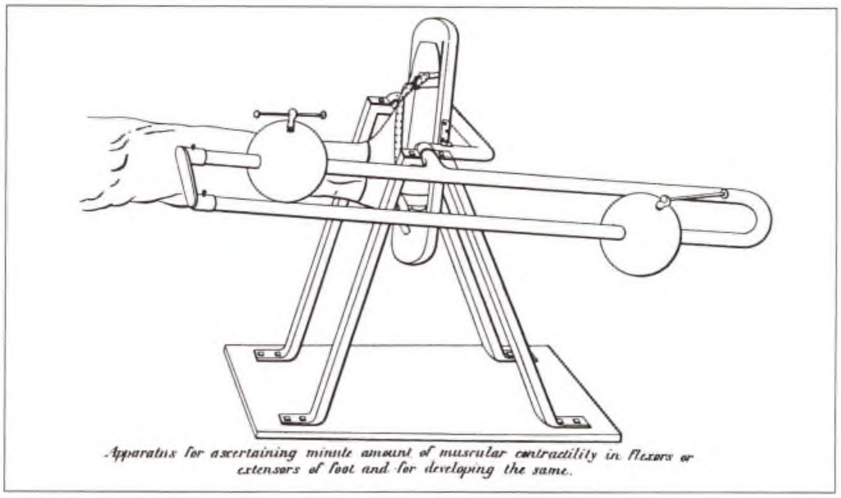

Figure 7.6

Figure 7.7

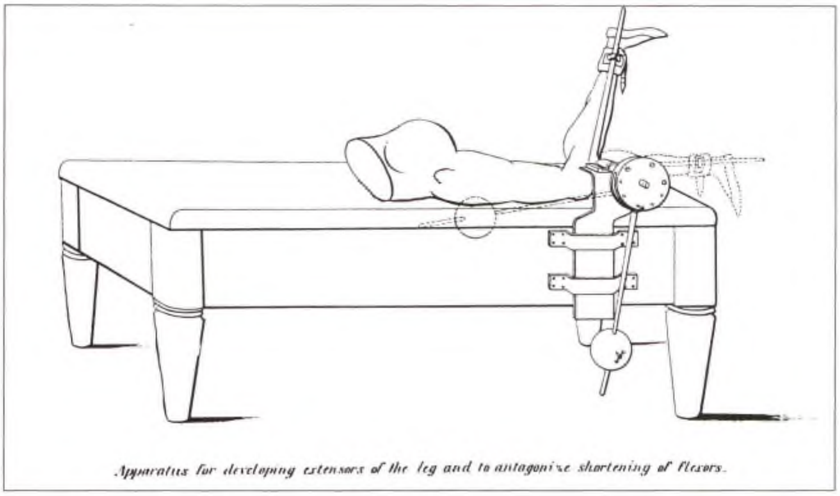

Figure 7.8

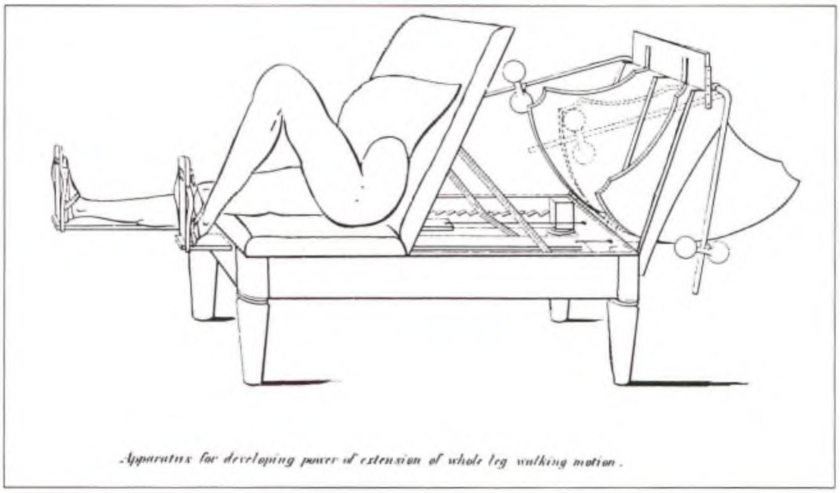

Figure 7.9

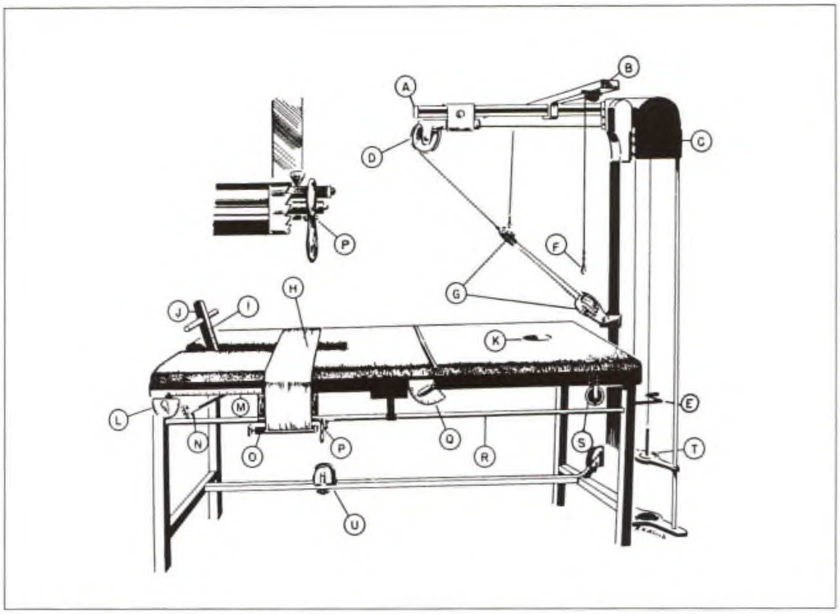

Figure 7.10 The complete exercise unit for administering progressive resistance exercises. From Thomas L. DeLorme and Arthur L. Watkins, *Progressive Resistance Exercise* (New York: Appleton-Century-Crofts Inc., 1952), 7.

First described in 1918 by Auguste Dejerine-Klumpke (1859–1927) as occurring in patients with spinal cord injuries, it was reported in patients with paralytic poliomyelitis in 1951.[36] The second, progressive contracture of fascia and fibrous tissue, was a major cause of deformity.

The fibrous tissue contractures that occurred during the late stages of paralytic poliomyelitis, while similar in type to those occurring in many other conditions, were much greater in degree and severity, and contributed as significantly to the disability as the paralysis and muscle weakness. The contractures were most severe in the lower extremities about the hip, knee joints, and feet, although they could occur in the lower back and upper extremities. The contractures were best treated by prevention with proper splinting during the acute phase of the disease and by continuous programs of therapeutic stretching exercises for indefinite periods afterwards. When prophylaxis failed, the contractures were addressed surgically by means of fasciotomy.

A fasciotomy was an operation that divided the tight fibrous covering over a muscle preparatory to dividing the muscle below (myotomy), the division of the fascial attachment of a muscle or muscle group from its origin or insertion, or the division of a firm fascial band such as the iliotibial band alone. Examples of such operations are Ober's operation for division of the *fascia lata* and iliotibial band at the hip for abduction flexion contracture of the hip, Yount's operation for division of the iliotibial band at its distal end, and Steindler's operation in which the fascia and muscles attached to the os calcis are stripped away.[37]


Figure 7.11 Arthur Steindler (1878–1959). From Joseph A. Buckwalter, "Arthur Steindler: Founder of Iowa Orthopedics," *Iowa Orthop J* 1(1981): 5–12.

Arthur Steindler (1878–1959) (figure 7.11) was born in Graslitz, Czechoslovakia, and received a classical education in Vienna, where he graduated from the medical school in 1902.[38] After his early orthopedic training in Vienna, Steindler became an assistant in 1907 to John Ridlon, Hugh Owen Thomas's American advocate, at the Home for Cripped Children in Chicago. In 1910, with the encouragement of Ridlon, Steindler accepted the position of professor of orthopaedic surgery at Drake University in Des Moines, Iowa. Two years later he joined the University of Iowa in Iowa City, where he built a strong, academically oriented orthopedic program. During the next thirty-seven years, through his own efforts and the work of his students, he contributed significantly to the growth of the specialty of orthopedics. Steindler published an unusual book on operative technique in which not only are operations discussed, but the results of these operations are summarized by the author.[39] This was possible not only because he had extensive experience but also because of his long-term follow-up of his patients, which was very complete. This work provides a good summary of the orthopedic operations being performed at the midpoint of the twentieth century.

Many deformities due to contractures of fascia, muscle, or muscle groups could be treated by simple tenotomy, myotomy, or fasciotomy. In the absence of a such contractures, these procedures were of no value. Having prevented or corrected such a deformity, was there some way to provide active muscular action to strengthen, stabilize, or replace the lost muscle function? In the poliomyelitis patient it was not unusual to see weakness or paralysis in one group of muscles in association with normally functioning adjacent groups. Could Peter be robbed to pay Paul? That is, could one of the strong muscles be used to perform the function of one of the paralyzed muscles? The first surgeon to explore this hypothesis was Karl Nicoladoni (1847–1902) (figure 7.12). Nicoladoni was born and educated in Vienna, where he trained at the First Surgical Clinic under the direction of Johann Dumreicher. After a period in Innsbruck, he became professor of surgery in Graz at the Carola-Franzisca Universität. Nicoladoni was a very innovative surgeon who made major contributions to abdominal surgery as well as to orthopedics. In 1881, while in Innsbruck, he reported three patients with foot deformities (calcaneous feet) due to paralysis of the calf muscles.[40] On 15 April 1881, he operated upon one of these patients, a sixteen-year-old boy who had developed poliomyelities at the age of two. After dividing the peroneal tendons at the lateral malleolus, Nicoladoni inserted their proximal ends into the Achilles tendon. His assistant during the operation, Adolf Lorenz, later called the "Father of Orthopaedic Surgery in Germany," belittled this "mad" idea of "a strange man," as he called his chief.[41] One month later Nicoladoni observed


Figure 7.12 Karl Nicoladoni (1847–1902). From Phillip J. Erlacher, "The Development of Tendon Surgery in Germany," *AAOS Instructional Course Lectures* 13(1956): 110–15.

that electrical stimulation of the peroneal muscles caused the foot to flex plantarward. By the middle of July the patient could do this actively. The idea caught on rapidly. Joel E. Goldthwaite of Boston enthusiastically reported upon his experience with the operation and suggested that there was no reason why the same principle could not be employed in other parts of the body.[42] In New York City, Samuel Milliken took up the operation and after reporting his first case in 1895, followed with a report of fourteen additional operations on nine patients in 1896.[43] Alessandro Codivilla (1861–1912) (figure 7.13), the director of the Rizzoli Institute of Bologna, published an important paper on tendon transfer in 1899.[44] He introduced the technique of transfering the posterior tibialis muscle and tendon through the interosseous membrane between the tibia and fibula to restore active dorsiflexion of the foot. He described a tendon transfer to restore opposition of the thumb. In another application of the technique, he carried out an Achilles tendon transfer in a patient with a spastic equinus deformity associated with cerebral palsy.

Figure 7.13 Alessandro Codivilla (1861–1912). From *Sci med ital* 4(1956): 537.

While the European surgeons were happy with the results of tendon transfer alone, their colleagues in the United States were more inclined to carry out combined procedures. Royal Whitman (1857–1946) at the Hospital for the Ruptured and Crippled in New York was dissatisfied with the results of the use of tendon transfer alone to stabilize the feet of poliomyelitis patients with a calcaneous deformity. To "balance the foot" he advocated that in addition to a tendon transfer, a bony procedure, usually astragulectomy and posterior displacement of the foot or an arthrodesis, should be done as well.[45] The development of operations to produce arthrodesis of the bones of the foot, wrist, and hand went on synchronously with the development of operations for tendon transfer. Albert Hoffa (1859–1907) in Berlin emphasized the importance of correcting any fixed deformity prior to attempting tendon transfer.[46] This principle, reiterated by Robert Jones in 1911, quickly became well accepted.[47]

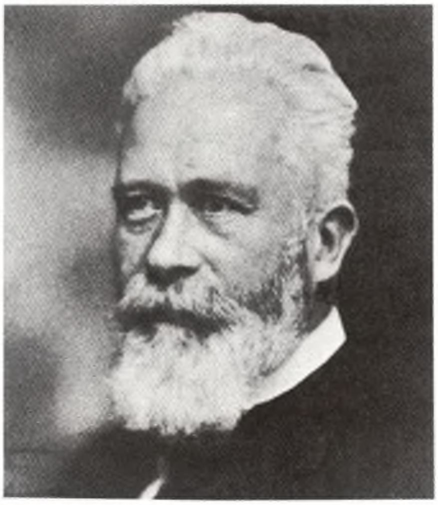

Figure 7.14 Oskar Vulpius (1867–1936). From Erlacher, "Development of Tendon Surgery," 110–15.

Oskar Vulpius (1867–1936) (figure 7.14) in Heidelberg had a distinguished career dedicated to the treatment of those crippled by disease and injury.[48] His interest in the treatment of patients with poliomyelitis is evident in his publications.[49] The technique for attaching the end of the tendon to be transfered was important. Vulpius advocated fastening it to the tendon of the paralyzed muscle close to its insertion, as had been done by Nicoladoni. This approach was condemned by many of his colleagues who urged that the end of the tendon be firmly attached to the periosteum or underlying bone. Leading this group was Fritz Lange (1864–1952) (figure 7.15). Lange had studied in Strasbourg and Vienna before moving to Munich, where he began his work in the Polyclinic.[50] Here he built a strong orthopedic group and

Figure 7.15 Fritz Lange (1864–1952). From Erlacher, "Development of Tendon Surgery," 110–15.

Figure 7.16 Konrad Biesalski (1868–1930). From Erlacher, "The Development of Tendon Surgery," 110–15.

established a state-supported program for cripples throughout Bavaria. Many of his students became professors of orthopedics in German universities. When the tendon was too short to be easily implanted, Lange prolonged the tendon by means of heavy silk sutures.[51] The use of sutures to extend the length of the tendons was used extensively, although the method was more popular in Europe than in the United States. Leo Mayer described the result.

A strand of silk when implanted to replace a paralyzed tendon does not remain an inert foreign body, but is rapidly surrounded by a tube of connective tissue which in time may become as thick as a finger and assume microscopically many of the characteristics of tendon tissue. The silk itself then acts as a core, the main work being done by the enveloping pseudotendon.[52]

Lovett gives a good description of this method as well as the use of silk sutures as a ligament or for tenodesis.[53]

The scientific study of tendons and tendon transfers began with the work of Konrad Biesalski (1868–1930) (figure 7.16) in Berlin.[54] Biesalski had a major influence on the development of orthopedics in Germany. Through his work at the Oskar-Helen-Heim Hospital, where he had a large orthopedic clinic, he was a great contributor to the development of government programs for the care of cripples. He also exercised major influence as a writer and editor of orthopedic publications. In his work on tendons, which is summarized in his book on the physiology of tendon transfer, he had as his collaborator a young surgeon from the United States, Leo Mayer[55] (1884–1972) (figure 7.17). Mayer had begun his work in Munich in 1912 under the aegis of Fritz Lange, but had moved to Berlin to work as an assistant to Biesalski. Forced to return to the United States because of World War I, Mayer summarized this work in a series of articles in *Surgery, Gynecology and Obstetrics.*[56] Biesalski and Mayer believed that it was important to route the transfered tendon as much as possible through the sheath of the tendon being replaced. In his Moynihan Lecture in 1952, Mayer stated his principles for tendon transfer.

Thou shalt not traumatize the tendon, or its sheath, or the paratenon, or any part of its gliding mechanism.

Thou shalt preserve the normal relationship between the tendon and its sheath.

Thou shalt place the skin incisions with due regard to normal creases and lines of tension.

Thou shalt restore the normal tension to the tendon.

Thou shalt respect the vascular supply of tendons and every detail of their anatomy and the mechanical laws governing their action.[57]

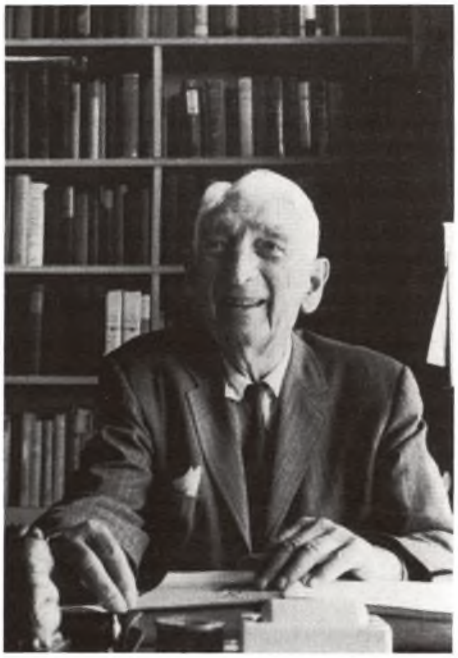

Figure 7.17 Leo Mayer (1884–1972). From *J Bone Joint Surg* 53A(1972): 1804.

Mayer was born in Alabama but was brought up and received his early education in New York City.[58] After graduating from Harvard he received his medical degree from the Columbia College of Physicians and Surgeons in 1909. Following three years of postgraduate training, he went to Munich in 1912 to study orthopedics with Fritz Lange, later going on to Berlin to work with Biesalski. Upon returning to the United States he busied himself with the problems of the crippled and handicapped. He was an outstanding teacher and held academic appointments at the New York Post Graduate Medical School and the New York University Medical School. After World War II he was instrumental in raising funds and in organizing orthopedic and rehabilitation services in Israel. The perfection of the techniques for tendon transfer in the upper extremities was largely the work of Sterling Bunnell of San Francisco, a close friend of Leo Mayer, and Robert Guy Pulvertaft the founder of the specialty of hand surgery in Great Britain.[59] Long-term results in patients with paralysis in the lower extremities due to poliomyelitis treated by tendon transfers were not uniformily successful or beneficial, although a significant number of the patients did obtain an increment of improved function.[60] In 1882 Professor Eduard Albert (1841–1900) (figure 7.18) of the First Surgical Clinic in Vienna reported four patients with paralysis in the lower extremities due to poliomyelitis in whom he had carried out an arthrodesis in order to stabilize the limb and to eliminate the need for external bracing.[61] Arthrodesis of the knee was carried out in three of these patients, and arthrodesis between the distal tibia and the astragulus in one. He concluded that only further experience would determine the value of such procedures.

Figure 7.18 Eduard Albert (1841–1900). From H. Killian and G. Kramer, *Meister der Chirurgie aus dem Chirurgischenschulen in Deutscher Raum* (Stuttgart: Georg Thieme, 1951), fig. 27.

Albert was the son of a Bohemian watchmaker. Educated in Vienna, he became a protégé of Carl Rokitansky and in 1881 became the director of the First Surgical Clinic over the opposition of Theodor Billroth, the director of the Second Surgical Clinic. He was an outstanding teacher and writer who, while contributing to surgery broadly, was especially influential in establishing orthopedics as a specialty in Vienna.[62]

The operations that led to the development of what is now called the *triple arthrodesis* have a long history, which was summarized by Vernon Hart and R. P. Schwartz.[63] The first arthrodeses in the foot were carried out by L. von Lesser in Leipzig in 1879.[64] Whitman at the Hospital for the Ruptured and Crippled in New York City preferred to perform astragulectomy with posterior displacement of the foot, accompanied by tendon transfers to balance the foot. This posterior displacement of the foot was an important principle that became incorporated in many operations to stabilize the foot by arthrodesis. Whitman also occasionally performed arthrodesis of the ankle and other joints in the foot, depending upon the individual case.[65] Edwin W. Ryerson (1872–1961) (figure 7.19) of Chicago described the triple arthrodesis (fusion of the subastragular, astragulo-navicular and calcaneo-cuboid joints), in 1923.[66] Ryerson had been educated at Harvard and was a house officer at the Boston Children's Hospital before studying abroad in Berlin and Vienna. He began his practice in Chicago, where he was an important teacher in several of the medical schools. He served as president of the American Orthopaedic Association in 1925 and was the first president of the American Academy of Orthopaedic Surgeons in 1933.[67] His operation quickly replaced the variety of other procedures then in vogue. In a report of the end results of the triple arthrodesis, A. Smith and H. L. Von Lackum concluded:

Figure 7.19 Edwin W. Ryerson (1872–1961). From "A Tribute to the First President of the American Academy of Orthopaedic Surgeons," *J Bone Joint Surg* 47A(1965): 1274–75.

1. *Subastragular arthrodesis is an operation of great usefulness and wide applicability for stabilization of the foot if correctly done, but it is one of the most difficult operations to perform and demands from the surgeon much skill and experience as well as meticulous after-care.*
2. *It is of prime importance to displace the foot backward beneath the astragulus as well as to get it in a neutral lateral position.*
3. *The astragulus is stable in the majority of cases. In the few in which it is not, subastragular arthrodesis can still be done successfully provided the foot is well placed laterally and antero-posteriorly.*
4. *The operation is adapted to nearly every type of foot deformity. In this series the best results were in calcaneal feet.*
5. *The operation may be performed as early as the sixth or seventh year.*
6. *The poor results are due in every case to failure to obtain good position of the foot at operation, to removal of plaster support too soon after operation, to failure to obtain fusion, or to disregard of the torsion of the tibia. These errors were the result of our ignorance of the function and mechanics of the foot.*
7. *The optimum result can be obtained in practically all cases provided these conditions are fulfilled.*[68]

Just as tenodesis was a modification of tendon transfer, the development of bone blocks to limit plantar flexion or dorsiflexion of the ankle was associated with the development of arthrodesing operations. They could be performed alone or in association with triple arthrodesis. The posterior bone block described by Willis Campbell and the anterior bone block of Vittorio Putti are examples of this.[69] The modification of the technique of

Figure 7.20 David S. Grice (1914–1960). From *J Bone Joint Surg* 43A(1961): 319–20.

triple arthrodesis by C. Lambrinudi to incorporate a posterior bone block was widely used also.[70]

Wallace H. Cole (1888–1973) of St. Paul, on the basis of his large experience with tendon transfers and triple arthrodeses, stated that

any failures of these operations are due to 1) improper or insufficient operation, including failure to obtain correct posterior dislocation; 2) failure to balance the remaining muscle power; and 3) failure to remove sufficient wedges to completely overcome the existing deformity or deformities. Subastragular arthrodesis, either alone or combined with tendon transplantation or bone block, is indicated in a greater number of cases than any other one operation in the treatment of paralytic feet.[71]

Triple arthrodesis arrested the growth of the foot and because the affected foot in many patients was already small, the operation was postponed usually until late adolescence. Earlier stabilization of the foot was desirable and was achieved with the introduction by David S. Grice (1914–1960) (figure 7.20) in 1952 of an extra-articular fusion of the subastragular joint by means of bone grafts placed in the sinus tarsi.[72] Grice was a product of the University of Rochester and his orthopedic training was obtained at the Boston Children's Hospital and the Massachusetts General Hospital.[73] He remained associated with the Boston Children's Hospital and Harvard Medical School until he went to Philadelphia as the professor of orthopedics at the University of Pennsylvania. His major interest was in the care of patients with poliomyelitis. His death in an airplane crash in Boston Harbor cut short his career.

Differences in the lengths of the extremities are of clinical importance primarily in the lower extremities where they can affect the gait and the spine. They are of less importance in the upper extremity. Inequalities of leg length can result from a wide variety of conditions and traditionally had been corrected by some sort of lift. In 1916 R. Tunstall Taylor of Baltimore summarized his objections to this approach.

The unsightliness of the iron patten, the high cork or wooden-soled shoe, and the "extension shoe," that vicious mechanical device that throws the foot into extreme equinus and excoriates the heel cord by its retaining strap, — all present difficulties. To the poor the cost of these appliances is an obstacle; and to the poor and rich alike, the conspicuousness of such apparatus for life is a cause of self-consciousness, embarassment, sensitiveness and mortification.

Such cases are chiefly the result of tuberculosis of the hip or knee joints, fractures or infantile paralysis, but most often we see those that are the result of the first named.[74]

Figure 7.21 Francesco Rizzoli (1809–1880). From G. G. Forni, *L' Insegnamento della chirurgica nello studio di Bologna dalle origini a tutto il secol XIX* (Bologna: Capelli Editore, 1948), 165.

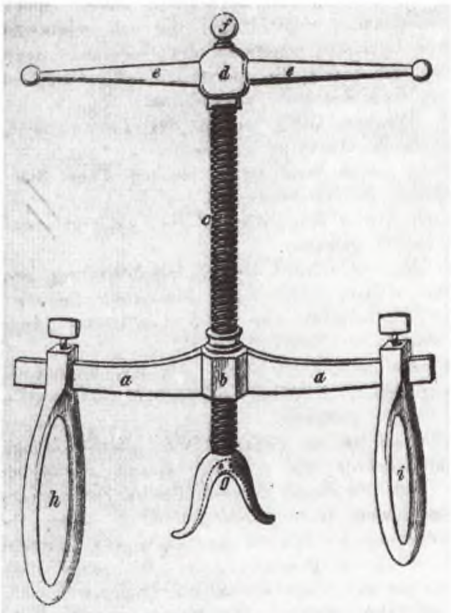

Figure 7.22 Rizzoli's osteoclast. From Rizzoli, "Das Übereinanderscheibung der Fragmente einer aufallig Fraktur des Femur," *Wien med Wschr* 19(1869): 1238–40.

Because of these dissatisfactions, surgeons have explored a number of methods of limb shortening or lengthening and found that, as incidence of tuberculosis was reduced and methods of treating fractures were improved, most of their patients needed treatment as a result of poliomyelitis. Shortening the long leg by means of elective osteotomy or resection in continuity had been proposed by Bernhard Heine,[75] but it was Francesco Rizzoli (1809–1880) (figure 7.21) who first reported in 1869 two cases in which he had equalized leg length.[76] His first patient, a forty-eight-year-old farmer, had five centimeters of shortening due to a femur fracture. When he had a second injury with fracture of the opposite femur in 1845, Rizzoli allowed it to shorten to the same length as the other leg. Heartened by the success of this experience, when he encountered a nine-year-old child in 1847 with a short leg caused by a fracture of the femur in infancy, Rizzoli fractured the normal femur, utilizing the recently introduced ether anesthesia and an osteoclast of his own design (figure 7.22) and allowed it to shorten, thus equalizing the leg lengths.

Rizzoli came from an old Bolognese family, studied at the University of Bologna and became professor of surgery and obstetrics and gynecology there in 1840. Although he had broad surgical interests, many of them focused on orthopedic subjects. Shortly before his death he gave all of his substantial fortune to found the Istituto Rizzoli. The institute occupied the site of an ancient monastery, later a convent, and contained a magnificent church dedicated to Saint Michele Arcangelo. The institute, not established until sixteen years after his death in 1896, became the major center for the development of orthopedic surgery in Italy.[77]

Other surgeons followed the lead of Heine and Rizzoli. Reginald Hall Sayre, the son of Lewis Albert Sayre, in discussing the paper by R. Tunstall Taylor stated:

I think it might interest Dr. Taylor to quote on this occasion the description of an operation that was done in New York in the year 1863 on a boy 10 years of age. I remember hearing my father speak of the fact that the boy had the limb shortened to match the other.[78]

By 1916 the procedure for femoral shortening was well established[79] (figures 7.23–7.24). J. Warren White summarized the literature and gave a good description of the technique in 1935.[80] The ultimate refinement of the method for femoral shortening was described by Gerhard Kuntscher, who used an intramedullary saw to resect a segment of the diaphysis and then stabilized the site with an intramedulary nail, all done blindly through a small incision over the trochanter![81] A technique for shortening the tibia and fibula was introduced in 1927 by John A. Brooke.[82] The advantage of the these procedures was that the amount of shortening could be carefully calculated and controlled.

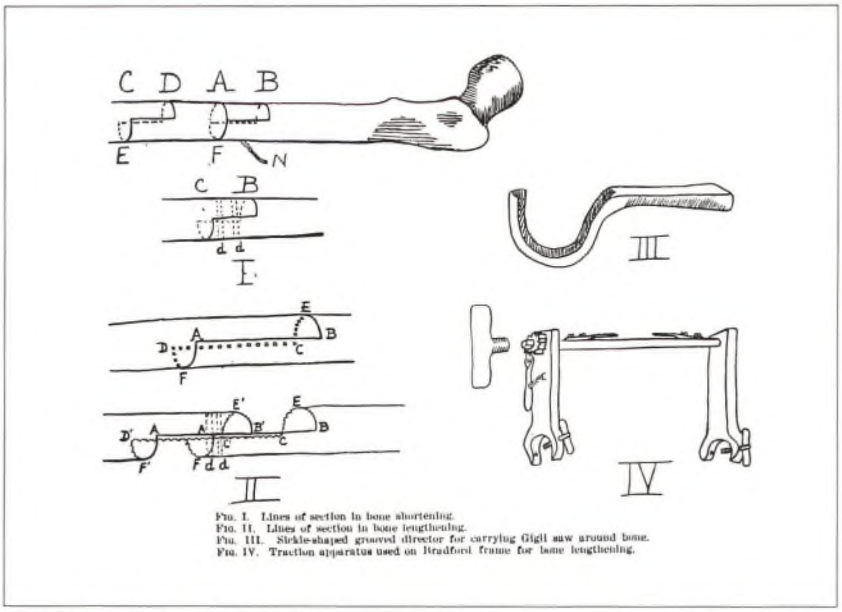

Figure 7.23 A technique for shortening the femur. From R. Tunstall Taylor, "Shortening Long Legs and Lengthening Short Legs," *Am J Orthop Surg* 14(1916): 600.

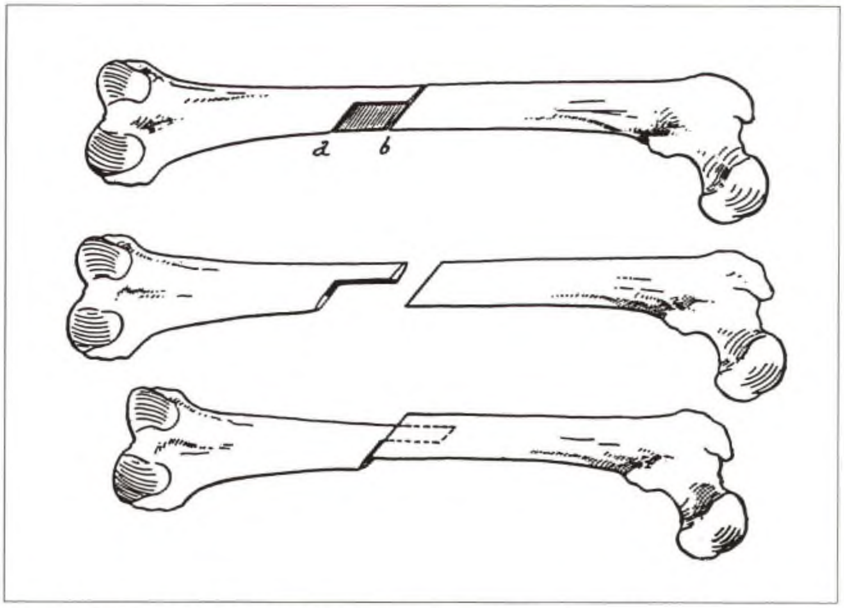

Figure 7.24 Another technique for shortening the femur. From Jacques Calve and Marcel Galland, "A New Procedure for Compensatory Shortening of the Unaffected Femur in Cases of Considerable Asymmetry of the Lower Limbs," *Am J Orthop Surg* 16(1918): 211–35.

Dallas B. Phemister introduced the technique of epiphyseodesis of the distal femoral and proximal tibial and fibular epiphyses of the long leg as a method of leg-length equalization[83] (figure 7.25). This operation became quite popular, but had some disadvantages, which were discussed extensively by John T. Hodgen and Charles H. Franz.[84] They believed that the most difficult and most important aspect of the operation was determining the time at which the growth of the epiphysis or epiphyses was to be arrested in order to obtain optimum correction.

S. L. Haas attempted to simplify epiphyseal arrest by introducing a wire loop through the epiphysis and metaphysis to prevent growth. By introducing a small loop through one side of the epiphysis and metaphysis, he also attempted to correct angulation deformities.[85] Haas's work suggested to Walter P. Blount that staples might be used instead. Blount noted that W. Arbuthnot Lane had reported that staples inserted across an epiphyseal line would result in growth arrest.[86] In 1949 Blount and George Clarke described the technique of controlling epiphyseal growth by stapling as a method of leg-length equalization[87] (figure 7.26). In a further report in 1952, Blount and Frank Zeier concluded that staples could be left in place for up to two years and then removed with expectation of resumption of growth.[88] Stapling was a simpler, less traumatic operation, and because the staples could be removed in case of a miscalculation, possessed some advantages over epiphyseodesis. However, design and material problems led to frequent breaking and or backing out of the staples. Some of the uncertainty regarding the timing of the interference with epiphyseal growth was removed by the growth-prediction charts published by William T. Green and M. S. Anderson in 1947 and revised in 1963.[89]

In 1903 Codivilla introduced a method of femoral lengthening in which he utilized strong skeletal traction applied gradually after an osteotomy performed by means of a pin placed in the *os calcis.*[90] Using his technique primarily in patients with malunited fractures he was able to gain between three to eight centimeters in length. This was the first example of the application of skeletal traction by means of a pin.[91] Albert H. Freiberg introduced Codivilla's method into the United States.[92] In 1913 Paul B. Magnuson performed a Z-osteotomy on the femur in dogs and, after elongation, fixed the osteotomy site with ivory screws.[93] He also reported the results of a similar procedure in four patients. It was relatively more easily accomplished in the paralyzed limb of the poliomyelitis patient because there was less muscle force to overcome.

Vittorio Putti (1880–1940) (figure 7.27), Codivilla's successor as the surgeon-in-chief of the Rizzoli Institute, built on Codivilla's work, devising a less cumbersome, safer, and more efficient appa-

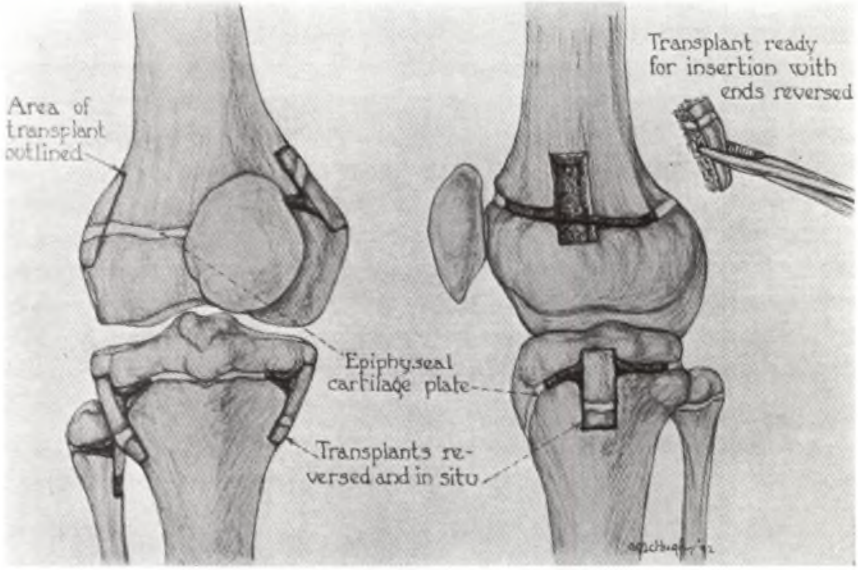

Figure 7.25 Epiphyseal arrest by epiphyseodesis. From Dallas B. Phemister, "Operative Arrest of Longitudinal Growth of Bones in the Treatment of Deformities," *J Bone Joint Surg* 15(1933): 1–15.

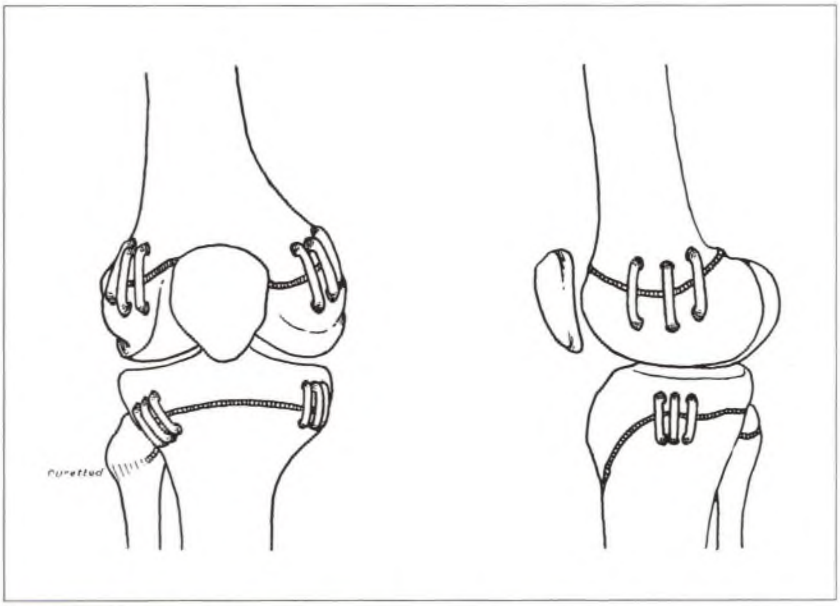

Figure 7.26 Epiphyseal arrest using staples. From W. P. Blount and G. R. Clarke, "Control of Bone Growth by Epiphyseal Stapling," *J Bone Joint Surg* 31A(1949): 464–78.

Figure 7.27 Vittorio Putti (1880–1940). From *J Bone Joint Surg* 23(1941): 188.

ratus for femoral lengthening, which he called an *osteoton.*[94] This consisted of two large pins for insertion into the femur above and below a Z-osteotomy. The pins were attached to an external bar that contained a calibrated screw device for elongation. He reported his results in the treatment of ten patients and was able to gain three to four inches in length. Putti had a large role in the development of orthopedic surgery in Italy and his influence was felt throughout the world. In addition to his clinical work, Putti's reputation was based on his role as a teacher and editor. He was a linguist who enjoyed traveling to international meetings, where he was a familiar figure. He left a substantial legacy to orthopedic surgery. Augusto Anzoletti has left a fine memoir dealing with the relationship between Codavilla and Putti and the early years of the Rizzoli Institute.[95]

Leroy C. Abbott (1890–1965) (figure 7.28) improved Putti's technique and promoted the procedure in the United States. In 1927 he reported six patients with poliomyelitis upon whom he had operated (figure 7.29). However, he cautioned that

with the operation in its present stage of development, we believe that it should be performed only by those who are adequately equipped to do bone surgery and who by their training have a thorough knowledge of mechanical appliances.[96]

Abbot was a graduate of the University of California School of Medicine in San Francisco. He had extensive experience with the treatment of injuries during World War I and studied with Sir Harold Stiles in Edinburgh after the war was over. Returning from Europe in 1920, he spent three years on the faculty of the University of Michigan before moving on to Washington University, St. Louis, where he was chief surgeon of the Shriner's Hospital for Crippled Children. In 1930 he returned to the University of California, where he organized and led an outstanding Department of Orthopedic Surgery until his retirement in 1957. In addition to his work in children's orthopedics, he is remembered for his outstanding anatomical teaching films.[97]

Figure 7.28 Leroy C. Abbott (1890–1965). From *J Bone Joint Surg* 48A(1966): 1455.

Complications of leg-lengthening procedures included angulation, valgus deformity, equinus deformity, osteomyelitis, delayed union, and nonunion.[98] Harold A. Sofield in a report on the long-term follow-up of forty of his patients some twenty years after leg-lengthening procedures were performed, concluded that such operations were seldom indicated.[99] M. V. Anderson of Edinburgh further developed the technique in 1952, and lengthening operations have continued to interest orthopedic surgeons.[100] More recently the work of G. A. Ilizarov and his group has spurred new interest in limb lengthening.[101]

It was well known that overgrowth, presumeably due to epiphyseal stimulation, occurred in some patients following fractures and osteomyelitis. Harold R. Bohlman carried out extensive ani-

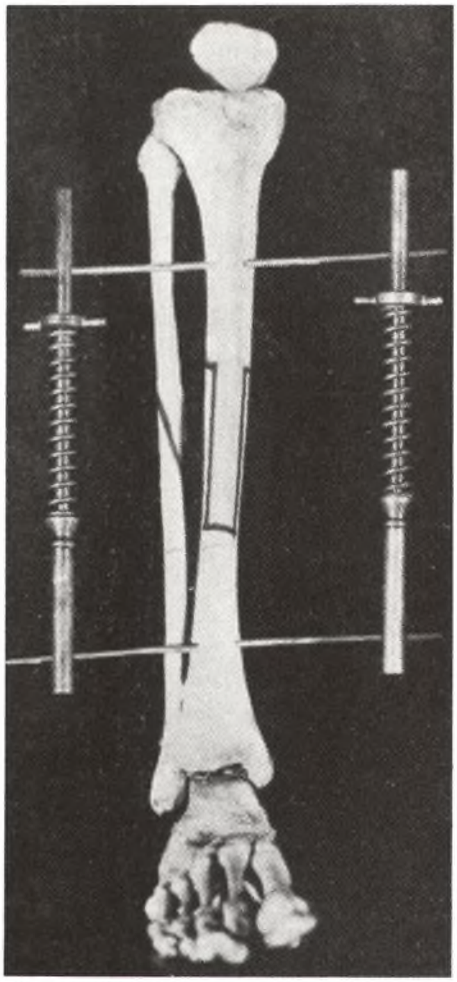

Figure 7.29 The apparatus used by Abbott for leg lengthening. From Leroy C. Abbott, "The Operative Lengthening of the Tibia and Fibula," *J Bone Joint Surg* 9(1927): 128–52.

mal experiments consisting of the implantation of twenty-one different materials in the metaphysis adjacent to the epiphysis in an effort to produce stimulation.[102] After reviewing the literature and his experimental data, he concluded that the amount of stimulation was negligible. Charles N. Pease implanted screws made of Vitallium, stainless steel, Vanadium, brass, and ivory in a similar manner with similar results.[103] He reported that in seven patients in whom he had inserted ivory screws in the distal femoral metaphyses, there had been some overgrowth in four. Epiphyseal stimulation by local implantation of foreign materials did not appear to be a useful or reliable method of gaining limb length.

Realizing that in patients with congenital arteriovenous fistulas in the extremities there was an associated bony overgrowth, Joseph M. Janes and his colleagues at the Mayo Clinic studied the effects of the production of a femoral arteriovenous fistula on the growth of the leg in dogs.[104] In five dogs they noted some increased growth. Several years later they reported that in a six-year-old girl with a short leg associated with poliomyelitis, the presence of an arteriovenous fistula decreased the leg-length inequality by three centimeters.[105] Although the technique had a clinical trial, a report on the results in fifty-three patients ten years later was not encouraging.[106] David G. Vesely performed the operation in fifty-six patients of whom forty-seven had had poliomyelitis.[107] He concluded that although there had been no serious complications of the procedure, the results were too variable and unpredictable to recommend it. Efforts to stimulate the short leg to grow by altering the circulation with a lumbar sympathectomy were not successful for the same reasons.[108] While some stimulation occurred in some patients, the results were unpredictable, although the trophic condition of the limb might be improved.

The rehabilitation of paralyzed poliomyelitis patients required an extensive knowledge of anatomy and an appreciation of kinesiology. Each patient presented a special problem for which an individual solution had to be sought. The application of general principles to such particular problems was quite a challenge and stimulated the best minds of several generations of orthopedic surgeons.

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CHAPTER EIGHT

Scoliosis

In contrast to the gibbus or kyphosis associated with Pott's disease, which is caused by a tuberculous infection of the vertebrae, lateral deviation of the spine, or *scoliosis*, is a deformity that has many causes, some of which are still not completely understood.[1] Hippocrates recognized that all deformities of the spine were not associated with tuberculosis and commented that "there are many varieties of curvature of the spine even in persons who are in good health; for it takes place from natural conformation and from habit, and the spine is liable to be bent from old age, and from pains."[2] One of these varieties, scoliosis, he attributed to chronic poor posture, stating that "lateral curvatures also occur, the proximate cause of which is the attitudes in which these patients lie."[3] This concept of a postural etiology was to persist for the next two thousand years.

Nicolas Andry endorsed the Hippocratic belief and emphasized, for example, that for the spine to grow properly it was important that children be given proper chairs.

> *When one sits with the Body bended backward, the Back must necessarily be crooked inwards; and when one sits upon a hollow Seat, the Effort which one naturally makes, and without any design, to bring the Body to an Equilibrium, must of necessity make the Back still more crooked.*[4]

Having been given a proper chair, the child should be made to sit up straight in it (figures 8.1–8.2). The desk should be of a proper height so that the back was not bent while writing. He inveighed against high heels for children and advised that the stays or corsets given young children be regularly changed or adjusted for growth.[5] Almost two hundred years later, Robert Lovett, in a chapter on scoliosis entitled "Faulty Attitude" from

Figures 8.1–8.2 Left: A proper sitting posture. Right: a poor sitting posture. From Nicolas Andry, *Orthopaedia; or the Art of Correcting and Preventing Deformities in Children* (London: A. Millar, 1743), vol. 1, facing p. 86.

his monograph *Lateral Curvature of the Spine and Round Shoulders*, echoed this concern when he said, "Prolonged flexion of the spine is induced by school furniture which fails to support the back, by errors in vision which necessitate stooping over books in reading, and in careless attitudes of reading and sitting at home"[6] (figure 8.3).

Andry suggested several ways in which asymmetry of the shoulders could be corrected.

Another method of managing a Child when he either raises or depresses one Shoulder too much, is to put some sort of Burthen upon the Shoulder that is lowest, and let the highest quite alone; for the Weight upon the low Shoulder will oblige him to raise it up, and at the same time will make him depress the other.

The Shoulder that carries a Burthen rises always higher than that which is not loaded, and hence the central Line of all the Weight, both of the Body and the Burthen, passes through that Leg which sustains the Weight. If the Case was not so, the Body must tumble. But Nature has provided against this Inconviency, by making an equal part of the Weight of the Body to be thrown to the side opposite to that upon which the Burthen is laid, which makes the Equilibrium; so that the Body is thereby obliged to stoop so low on that side which is not loaded, till it bears an equal Share of the Weight that is upon the other side; whence it happens that the Shoulder which is loaded rises up, while the other which is free of the Burthen falls lower[7] [figures 8.4–8.5].

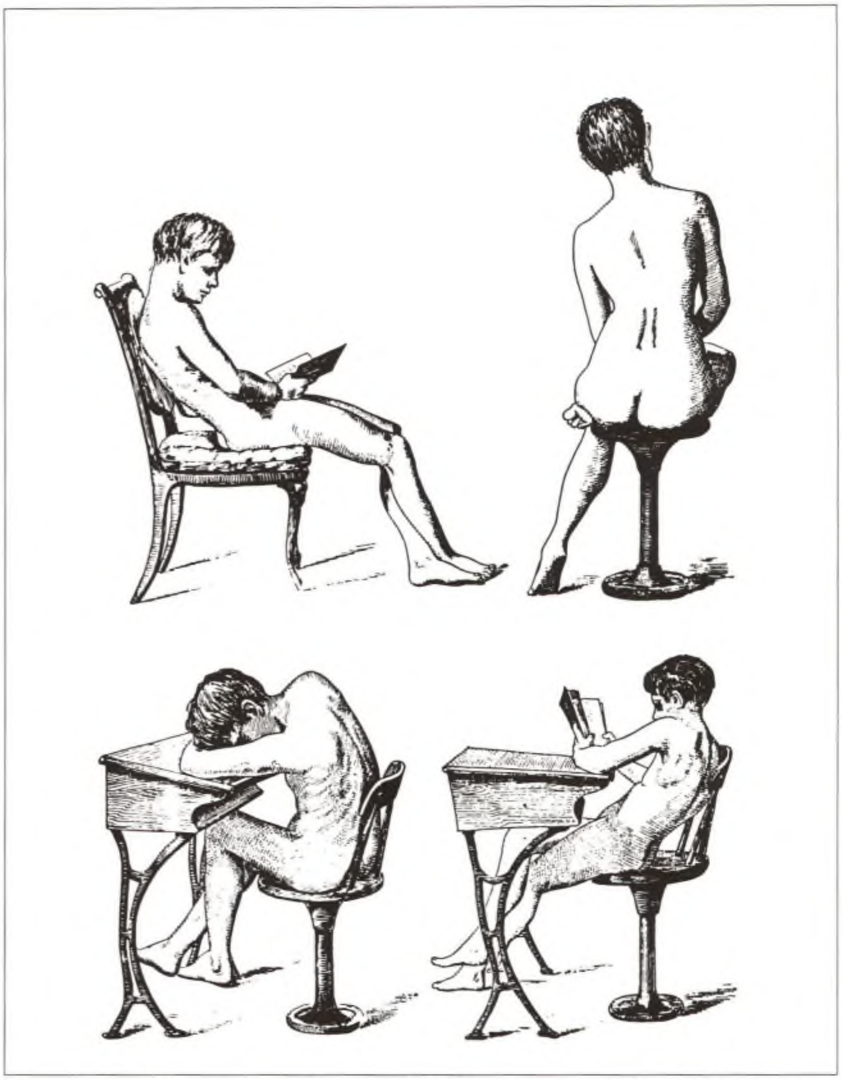


Figure 8.3 Examples of "faulty attitudes" believed to contribute to the development of scoliosis. From E. H. Bradford and R. W. Lovett, *Treatise on Orthopedic Surgery*, 2d ed. (New York: Wm. Wood & Co., 1899), 103.

In addition to these mild postural deformities of the back, Andry recognized more serious deformities. In a section from *Orthopaedia* discussing "Bunch-Back, Hollow-Back, and Crooked-Back," he gave this description:

> *These Deformities are the Effects of an ill-shaped Spine, which may proceed either from a Fall, or any Effort to lift something that is too heavy, as it happens frequently to Children when they carry one another; or from a Habit of crooking, bending or distorting their Bodies; or from a viscid Humour, which by relaxing the Ligaments displaces the Vertebrae of the Back, as it happens to Children that have got the Rickets; or lastly in the Birth from some violent Motion of the Child in its Mother's Belly.*

> *This Warping of the Spine is either outwards, or inwards, or both together. When it is outwards, it makes the Bunch-Back; when inwards, the Hollow-Back; and when it is both outwards and inwards,*

Figures 8.4 – 8.5 Dynamic correction of a high shoulder by loading the low side with a weight, either a heavy book or a ladder. From Andry, *Orthopaedia*, vol. 1, facing p. 119.

it makes the Crooked-Back; and it has then the Form of an S, either more streight like the S, or more crooked like the S.[8]

Andry believed that some of these cases were due to tight muscles and advised heat, massage, and stretching to loosen up contractures. He also advised the use of a "whalebone bodice, stuffed in such a manner that the stuffed parts shall exactly answer to those Protuberances which ought to be repressed."[9]

Andry's comments on the normal spine and its deformities point out the difficulties physicians have had in deciding which curves are within the normal limits of variation, which are nonprogressive, and which progress to serious deformity. Since treatment has always involved a serious committment by both the child and his parents, this is not an unimportant question. James Paget (1814–1899) addressed this problem in a short essay, "On Spines Suspected of Deformity."

Among the fears of disease for which one is consulted none is more frequent than that of lateral curvature of the spine. These fears are felt, especially, by mothers among the richer classes; and usually the fear is only for their daughters' spines. It is thought essential to the welfare of a young lady that her spine should be straight, and her form not notably ansymmetrical, and that she should habitually sit upright with her back unsupported. There is no such thought for young gentlemen, and it appears to be, chiefly, a consequence of this difference that in the well-to-do classes lateral curvature of the spine is at least twenty times more frequent in girls than in boys. For mothers seldom look at their sons' spines; and they let them sit with

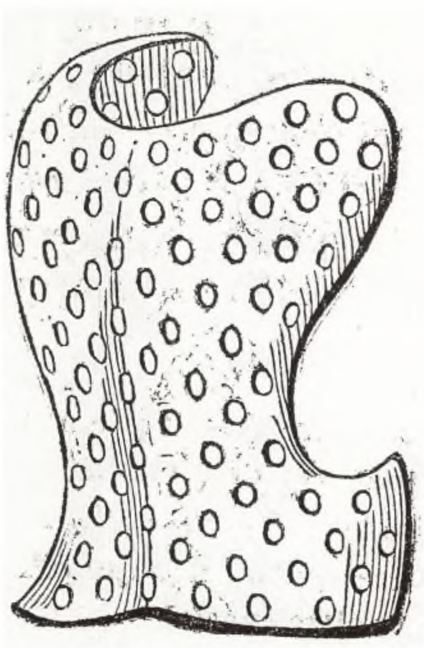


Figure 8.6 A *cuirasse*, or metal jacket lined with leather, used by Ambroise Paré for the treatment of scoliosis. From *Oeuvres complètes d'Ambroise Paré*, ed. J. F. Malgaigne (Paris: J. B. Baillière, 1840), 2:611.

their elbows on the table, loll back in their chairs, and lie flat on their stomachs, and do many more such prudent things as in the daughters would be deemed shameful. Thus the boys' spines grow straight; the muscles helping to support them are not over-tired, or, when they are, they can be rested in any comfortable posture. But among girls the postures deemed graceful must be maintained till some deformity is discovered or suspected and then the poor girls must be made miserable by the treatment deemed necessary for its cure.

The folly and mischief of this contrast are happily becoming known: the good rule of letting girls grow up like boys is becoming more and more widely observed, and a larger proportion of them are well-formed, graceful and strong.[10]

Having strongly expressed himself, Paget then goes into a description of the careful examination that must be made in a patient with a suspected back deformity, including visualization of the entire spine, observing the range of motion, looking for rib deformities with the back flexed, and measuring for leg-length discrepancy. He concludes:

I am conscious that this paper may seem to encourage a temper of mind which is in some of us habitual, and I suppose is in all occasionally felt — the temper that disposes one to make too light of a case, and be ready to think and say "There's nothing the matter." If I am in this risk of doing mischief I would try to prevent it by remindng the reader of the great difficulty of proving a negative, and that, as a general rule, it requires much more time and care in examing a patient to justify a decision that there is no disease than it does to ascertain what the disease is if there be any.[11]

Unfortunately, while functional, insignificant, and nonprogressive curves were numerous, there were also many patients who became seriously deformed in spite of these efforts.

The treatment of scoliosis required special equipment and apparatus, and for this reason tended to become a specialized area of practice. Initially, the skills that were needed were more mechanical than medical. The perforated metal corset lined with leather described by Ambroise Paré (1510–1590) in 1575 was undoubtedly made by an armourer[12] (figure 8.6). As the needs of society changed, some armourers and artificiers gradually evolved into manufacturers of surgical instruments and equipment. One hundred years after Paré, there was in Utrecht a crookedness clinic run by two brothers, Claes and Peter Schot, the sons of Jacob Claes Schot, a well-known brace and appliance maker. We have an interesting account of their management of a lateral curvature of the spine in the sixteen-year-old-son of an English nobleman.[13] The son, Edmund Verney, was sixteen years old when he was taken to Utrecht for treatment by his tutor in 1652.

There, over a period of four years, he was treated by a series of metal and leather harnesses that were adjusted and changed on a weekly basis. The tutor and the family were pleased with the result. This "crookedness clinic" was a busy place, employing sixteen or seventeen servants and three full-time brace makers in addition to the brothers. There were a large number of patients under treatment at any one time, and the treatment was expensive. The same type of an outpatient progam for the treatment of spinal diseases was carried on a little over one hundred years later by the physician Robert Chessher (1750–1831) in Hinckley, England.[14]

In London the brothers Timothy and William Shelldrake, who were brace and appliance makers, also engaged in the treatment of patients with lateral spinal curvature and other deformities. In 1783 Timothy Shelldrake published a book entitled *An Essay on the Various Causes and Effects of the Distorted Spine.*[15] Shelldrake used braces incorporating steel springs and his appliances were expensive. Henry Bigg was associated with Timothy Shelldrake in this business, which he passed on to his son and grandson.[16] The son, Henry Heather Bigg (1826–1881), had an engineering degree and had studied at St. George's Hospital. He was especially active in providing prostheses for veterans of the Crimean War. He published a book entitled *Orthopraxy: The Mechanical Treatment of Deformities, Debilities and Deficiencies of the Human Frame.*[17] The grandson, Henry Robert Heather Bigg (1853–1911), became a qualified physician and also published several books on the treatment of lateral curvature of the spine.[18] In Würzburg, the Heine family of brace and instrument makers, founded by Johann Georg Heine (1770–1838), the son of a farmer from Württemberg, developed their enterprise into an orthopedic institute. The next generation produced four distinguished surgeons and orthopedists.[19]

In contrast to Jean André Venel's establishment in Orbe, of which we know very little, the orthopedic institute of Delpech in Montpellier is well known because of descriptions and illustrations that he published in *De l'Orthomorphie* in 1828[20] (*see* chapter 2). In his treatment of scoliosis, Delpech relied primarily on programs of gymnastic exercises combining elements of stretching and muscle strengthening, and combinations of longitudinal and lateral traction (figure 8.7). He did not believe in the use of back braces. Delpech documented his results by the use of plaster of paris models made before and after treatment, and some of the results were good (figures 8.8–8.9)

The surgeon who reintroduced the operation of subcutaneous tenotomy into France was Sauveur-Henri Victor B. Bouvier (1799–1877) (figure 8.10), who carried out the procedure for the first time in Paris in 1835. Bouvier was born and educated in

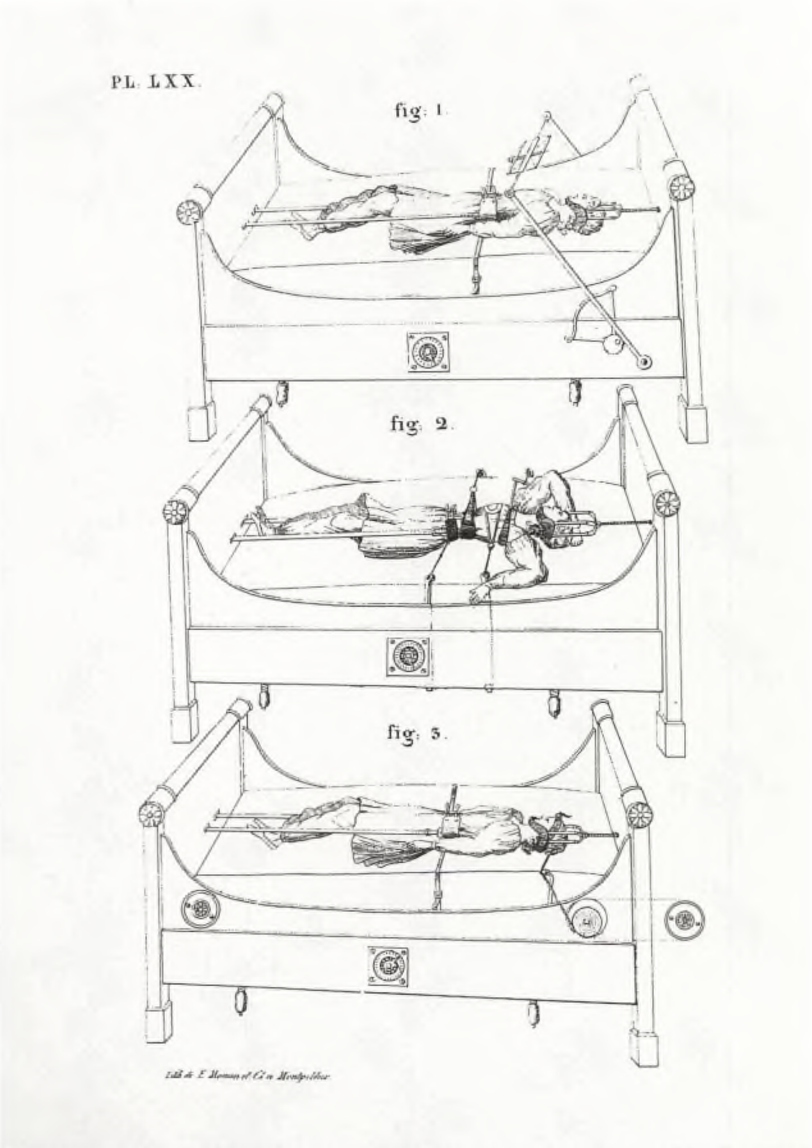


Figure 8.7 A couch used by Delpech to apply combinations of longitudinal and lateral traction in the treatment of scoliosis. From J. M. Delpech, *De l'Orthomorphie* (Paris: Gabon, 1828), atlas pl. 70.

Figures 8.8–8.9 The pretreatment model of a thirteen-year-old girl with scoliosis probably caused by poliomyelitis and the same patient after ten months of treatment. From Delpech, *De l'Orthomorphie*, atlas pls. 15–16.

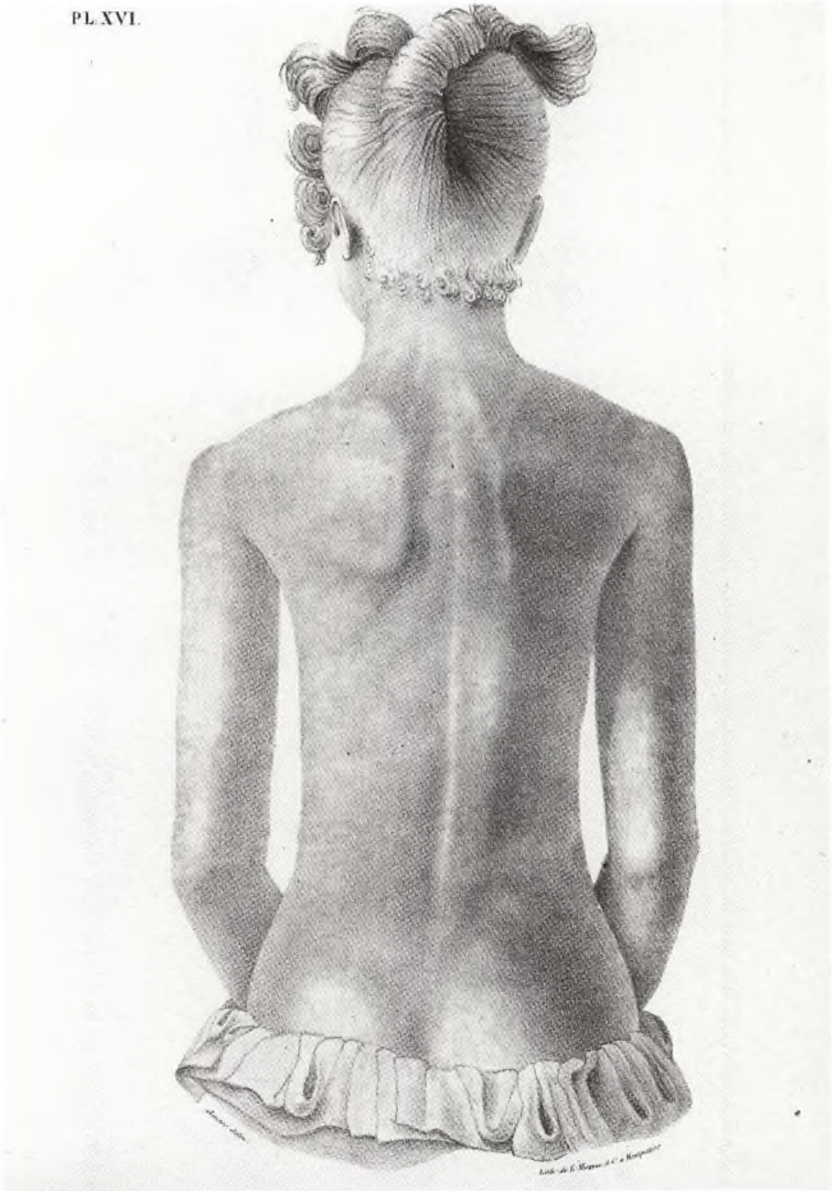


Figure 8.9

Figure 8.10 Sauveur-Henri Victor B. Bouvier (1799–1877). From Bruno Valentin, *Geschichte der Orthpäedie* (Stuttgart: Georg Thieme, 1961), 199.

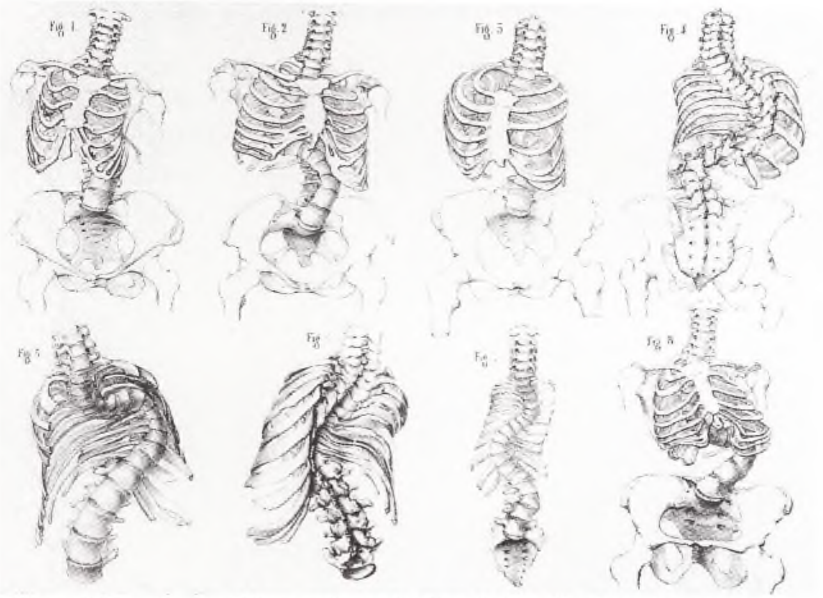


Figure 8.11 Some of the specimens in Bouvier's collection. From H. Bouvier, *Leçons cliniques sur les maladies chroniques de l'appareil locomoteur* (Paris: J. B. Baillière et Fils, 1858), atlas pl. 3.

Figure 8.12 Dissection of the trunk of a sixty-four-year-old woman with scoliosis demonstrating the displacement and adaptation of the internal organs to the deformity. From Bouvier, *Leçons cliniques*, atlas pl. 13.

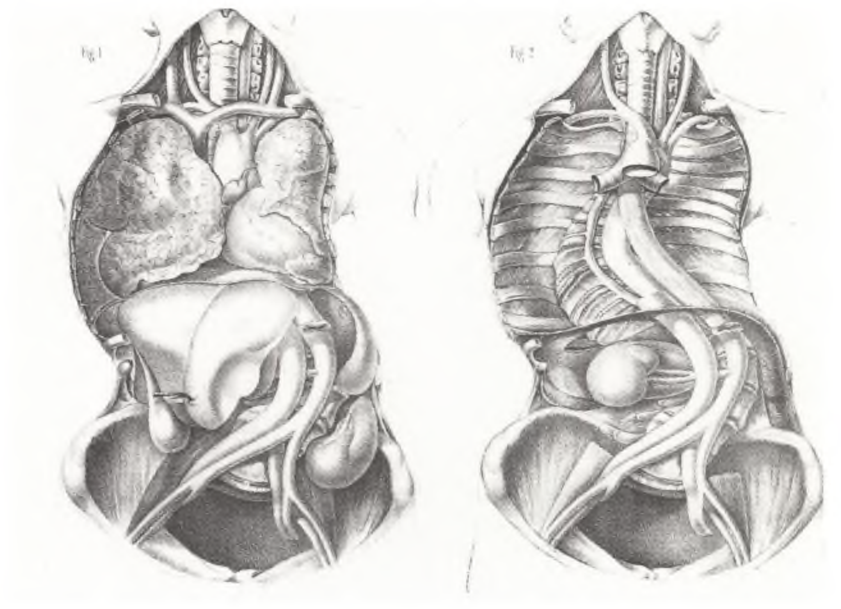


Figure 8.13 The trunk of a thirty-eight-year-old woman with severe scoliosis, with accompanying d*isplacement of the kidneys. From Bouvier, Leçons cliniques*, atlas pl. 18.

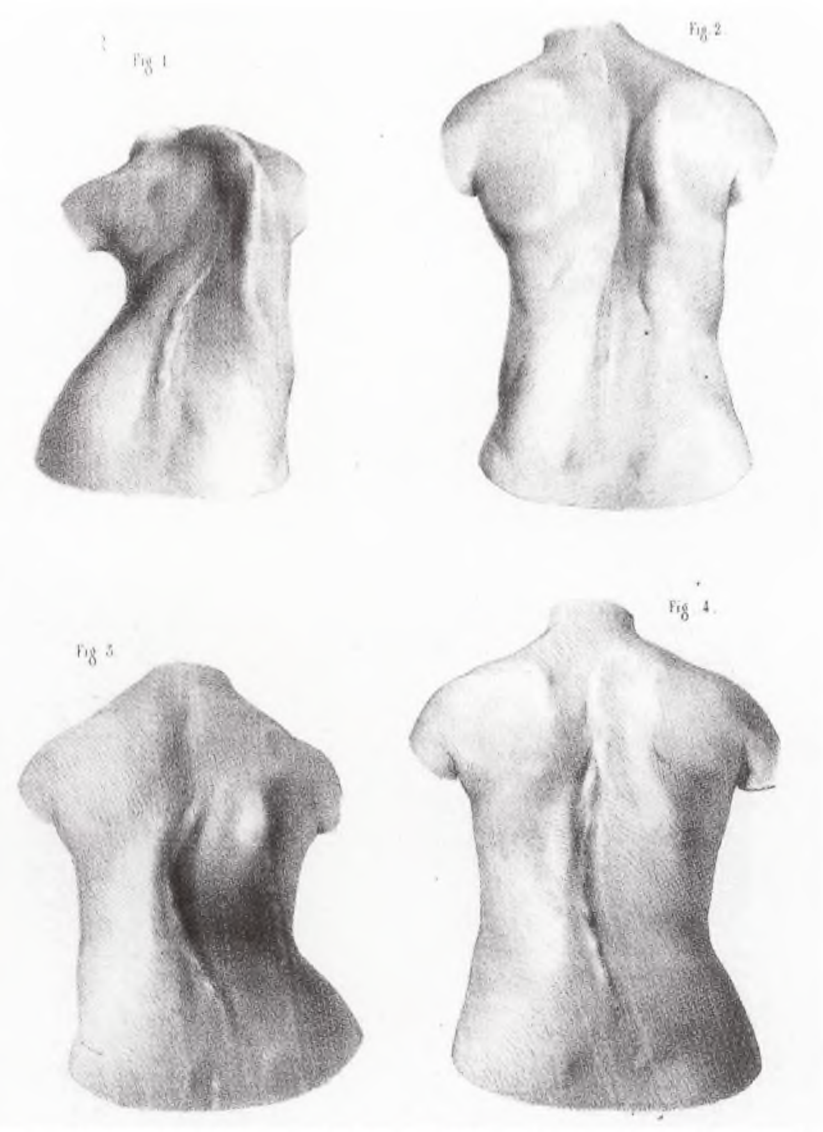
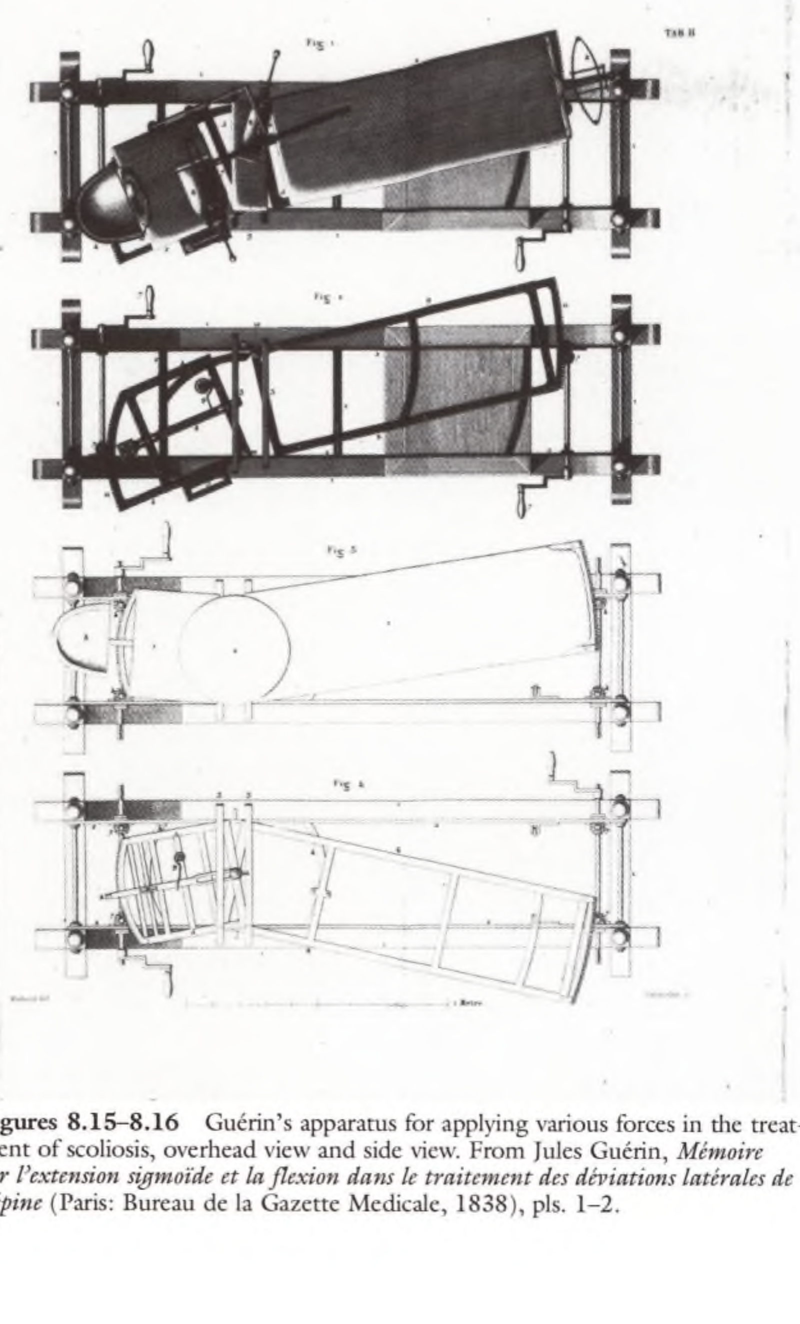


Figure 8.14 Two of Bouvier's patients. The upper figures are of a seventeen-year-old girl who was treated for two years with suspension, gymnastic exercises, and the application of traction and lateral pressure; the lower, a girl of fourteen treated similarly for six months. Both of these patients maintained their correction for at least a year. From Bouvier, *Leçons cliniques*, atlas pl. 19.

Paris. His first interest lay in anatomy and this probably accounts for the excellence of his work on the pathological anatomy of scoliosis. He established his own orthopedic institute in Paris and obtained a position at the children's hospital in 1831. A series of his lectures given at l'Hôpital des Enfants Malades in the years 1855, 1856, and 1857 were published in 1858 with the title *Leçons cliniques sur les maladies chroniques de l'appareil locomoteur.*[21] This was the first time that the subject of orthopedics had been equated with diseases of the locomotor system. Accompanying this volume of lectures was an atlas, which was unique and demonstrated the amount of material that he had available, as well as the care with which he took to study it (figures 8.11–8.13). Bouvier was well aware of the difficulties that the displacement of the heart, lungs, and abdominal viscera produced in his patients. For the treatment of his patients, Bouvier relied upon longitudinal traction in combination with lateral traction, suspension, and exercises. He did not believe that braces were of much value. Like Delpech, he had some success (figure 8.14).

One of Bouvier's colleagues in Paris was Jules Guérin, the first orthopedist to attack the problem of scoliosis with an operation. Guérin devised a special apparatus for the treatment of scoliosis that applied traction, lateral pressure, flexion and extension, and torsion[22] (figures 8.15–8.16). He believed that scoliosis was caused by muscle contractures or imbalance. After developing experience with subcutaneous tenotomy in the treatment of clubfeet, he applied this method to the division of tight muscles about the spine. He first described this approach in 1839.[23] During the next few years this surgical entrepeneur became the focus of controversy. When he published the results of the treatment of 1,349 patients who were treated by his orthopedic service he was attacked by his colleagues. In a leading article in his *Journal de chirurgie* Malgaigne wrote of "some orthopedic illusions" in association with Guérin's method.[24] The result was a famous trial for defamation, which concluded with a verdict in favor of Malgaigne and established the principle of free criticism of scientific articles.[25] Writing more than ten years after the trial, Bouvier attributed what good results Guérin attained not to the operations, but to the nonoperative methods of stretching and strengthening exercises that Guérin and others were using at the time.[26]

While programs of physical exercises for the treatment of scoliosis were also advocated in the United States by Charles Fayette Taylor (1827–1899), other nonoperative methods were being explored.[27] A major contribution to the treatment of scoliosis was made by Lewis A. Sayre (1820–1900) when he adapted the plaster of paris body jacket that he used for the treatment of Pott's disease to the treatment of scoliosis.[28] Utilizing vertical suspension to obtain correction, and the jacket for reten-



Figures 8.15–8.16 Guérin's apparatus for applying various forces in the treatment of scoliosis, overhead view and side view. From Jules Guérin, *Mémoire sur l'extension sigmoïde et la flexion dans le traitement des déviations latérales de l'épine* (Paris: Bureau de la Gazette Medicale, 1838), pls. 1–2.

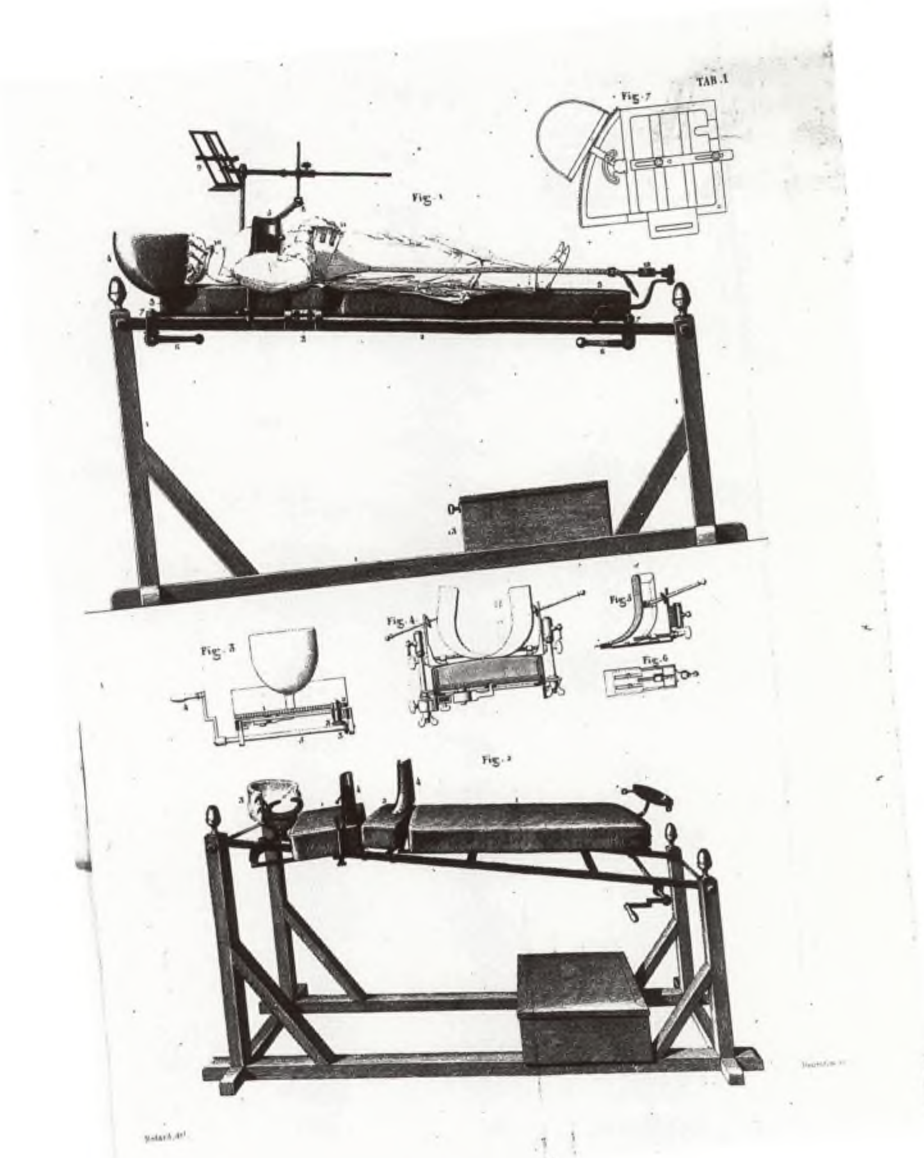
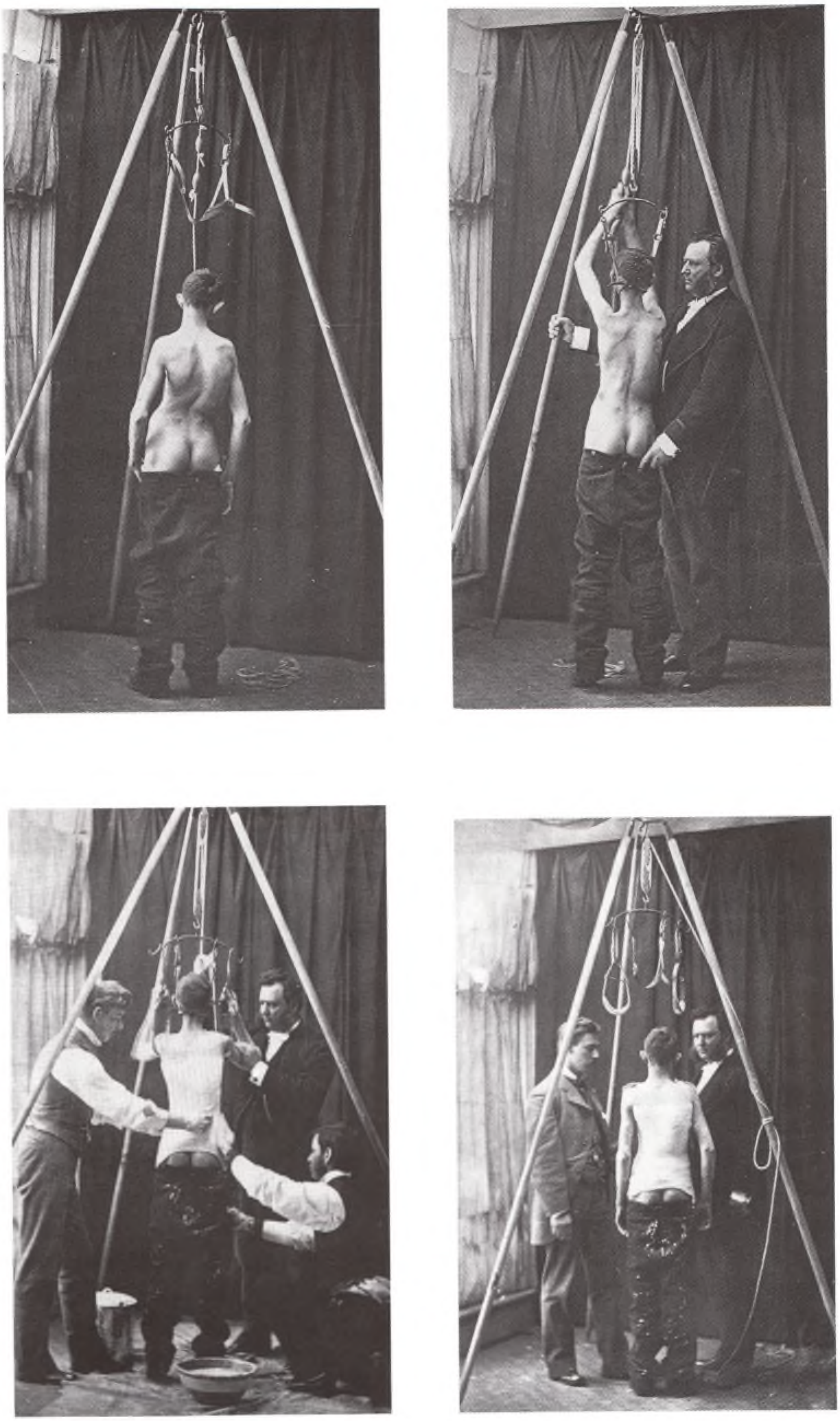


Figure 8.16

Figures 8.17–8.20 Photographs of Lewis A. Sayre supervising the application of a plaster of paris body jacket to a patient with scoliosis. From Sayre, *Spinal Disease and Spinal Curvature* (London: Smith Elder & Co., 1877), facing p. 105, pl. 2.



tion, Sayre provided physicians with a relatively inexpensive method of treatment that had wide application (figures 8.17–8.20). The jackets were changed at short intervals, initially, to obtain further correction. When maximum correction had been obtained, form-fitting corsets were substituted for the jackets (figure 8.21). These could be removed to permit the performance of muscle-strengthening and muscle-stretching exercises[29] (figure 8.22). The method of simple suspension was modified to permit lateral pressure (figures 8.23–8.24). Jackets were also applied with longitudinal traction and lateral traction in recumbency (figures 8.25–8.26). Alfred Shanz (1868–1931) in Dresden supplemented the use of strong longitudinal traction in suspension with episodes of strong, forcible manipulation of the fixed curves carried out under anesthesia, following which the patients were stretched again and a new plaster of paris jacket applied.[30] He compared this treatment with the manipulation of clubfeet and sought to overcorrect the deformity. F. Calot, not deterred by his experience with Pott's disease, submitted his patients to forcible *redressment* under anesthesia. Following this, the patient was placed in a plaster jacket with openings to permit the insertion of pressure pads. These *séances* were repeated every three months, and the patients were kept recumbent during the intervals.[31]

At a surgical congress in Berlin in 1889, Richard Volkmann presented two patients with severe rib deformities associated with scoliosis that he had treated by osteotomy and resection of a portion of the ribs. These cases were discussed in 1895 by Albert Hoffa (1859–1908) in his presentation of a similar case.[32] In Hoffa's patient the osteotomies of the ribs not only improved the cosmetic deformity but at the same time allowed further correction of the scoliosis itself by traction and manipulation. Michael Hoke (1872–1944) of Atlanta also reported a patient treated in this manner on whom he operated three times.[33]

One of the leaders in the study of scoliosis in the latter part of the nineteenth century was Wilhelm Schulthess (1855–1917).[34] Schulthess began his career as a practicing internist in Zurich. In 1883 he and an associate opened a private orthopedic institute, and from this point on his work was almost entirely devoted to this area. Schulthess was particularly interested in methods of measuring and recording the degree and type of the deformity (figures 8.27–8.28). His monograph on scoliosis provided a remarkable summary of the information available on the subject at the beginning of the twentieth century.[35] Robert W. Lovett (1859–1924) of Boston also thoroughly reviewed the status of the treatment of scoliosis in the United States in the early part of the twentieth century.[36]

In 1911, in his preliminary report of three patients with Pott's disease treated by spinal fusion, Russell Hibbs (1869–1932) sug-

Figure 8.21 A celluloid corset for the treatment of scoliosis. Note the similarity of the design to that of Paré. From Wilhelm Schulthess, "Die Pathologie und Therapie der Ruckgratsverkrummungen," in *Handbuch der Orthopaedischen Chirurgie*, ed. Georg Joachimsthal (Jena: Gustav Fischer, 1905–1907), 1:1047.

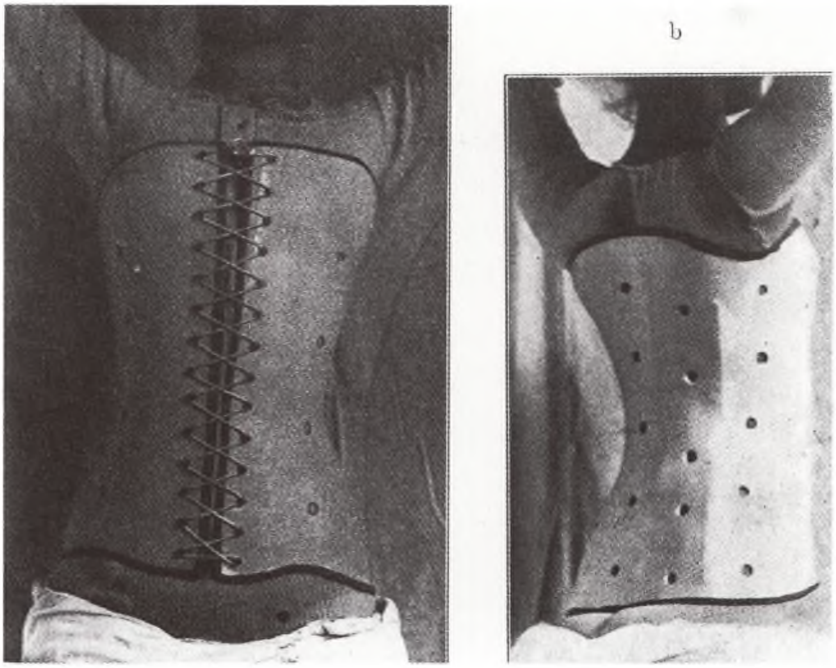
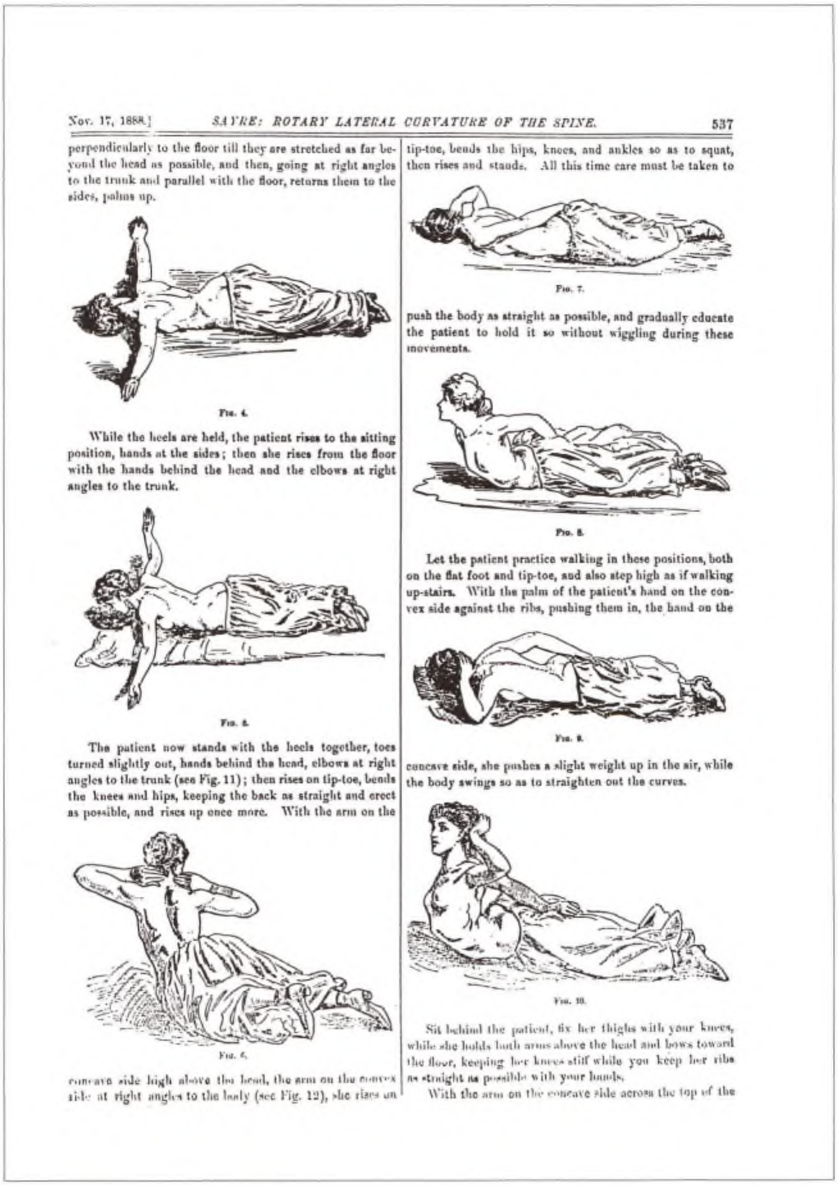


Figure 8.22 Some of the exercises used by the Sayres during the treatment of scoliosis. From Reginald H. Sayre, "Rotary Lateral Curvature of the Spine," *NY Med J* 48(1888): 537.



Nov. 17, 1888.] *SAYRE: ROTARY LATERAL CURVATURE OF THE SPINE.* 537

perpendicularly to the floor till they are stretched as far beyond the head as possible, and then, going at right angles to the trunk and parallel with the floor, returns them to the sides, palms up.

Fig. 4.

While the heels are held, the patient rises to the sitting position, hands at the sides; then she rises from the floor with the hands behind the head and the elbows at right angles to the trunk.

Fig. 5.

The patient now stands with the heels together, toes turned slightly out, hands behind the head, elbows at right angles to the trunk (see Fig. 11); then rises on tip-toe, bends the knees and hips, keeping the back as straight and erect as possible, and rises up once more. With the arm on the

Fig. 6.

concave side high above the head, the arm on the convex side at right angles to the body (see Fig. 12), she rises on tip-toe, bends the hips, knees, and ankles so as to squat, then rises and stands. All this time care must be taken to

Fig. 7.

push the body as straight as possible, and gradually educate the patient to hold it so without wiggling during these movements.

Fig. 8.

Let the patient practice walking in these positions, both on the flat foot and tip-toe, and also step high as if walking up-stairs. With the palm of the patient's hand on the convex side against the ribs, pushing them in, the hand on the

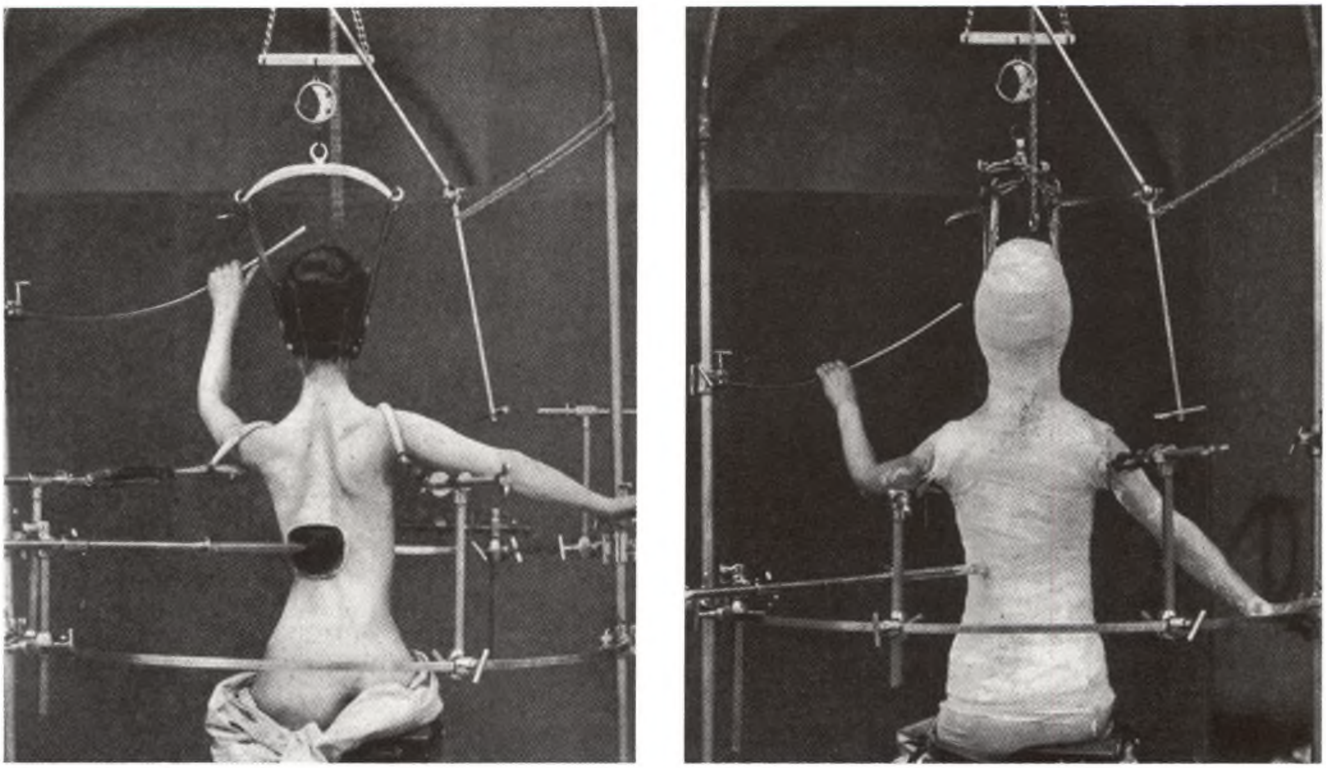
Fig. 9.

concave side, she pushes a slight weight up in the air, while the body swings so as to straighten out the curves.

Fig. 10.

Sit behind the patient, fix her thighs with your knees, while she holds both arms above the head and bows toward the floor, keeping her knees stiff while you keep her ribs as straight as possible with your hands.

With the arm on the concave side across the top of the



Figures 8.23–8.24 The application of a body jacket in the apparatus of Wullstein. Left: suspension and lateral pressure applied. Right: the completed jacket. From Schulthess, "Die Pathologie und Therapie der Ruckgratsverkrummungen," 1:1060–61.

gested that such an operation could also be used in the treatment of scoliosis.[37] The experience that he gained in carrying out spinal fusions for tuberculosis quickly bore fruit, and in 1914 Hibbs performed his first spinal fusion for scoliosis. Three years later Hibbs reported upon eight cases of scoliosis in patients with poliomyelitis that he had treated successfully with spinal fusion.[38] The technique was the same that he used in the treatment Pott's disease. The patients were treated with bed rest for eight weeks and then allowed up with a brace. Hibbs believed that such patients should be treated with a long fusion carried out early in the course of the deformity. John Ridlon (1852–1936), in discussing the paper, asked why the deformity should not be corrected before the operation. Between 1914 and 1919 Hibbs carried out fifty-nine spinal fusions for scoliosis, and following Ridlon's suggestion initiated preoperative correction in plaster jackets applied with strong longitudinal traction; he also used turn-buckle jackets.[39] Postoperatively the patients were treated in bed until the operative wounds had healed and then were placed again in corrective plaster of paris jackets. The patients were kept in bed for six weeks and then allowed up, though they were still required to wear a removable jacket for another six to twelve months. Hibbs concluded that the fusion operation prevented the further progress of the deformity and that the operation should be done early because it was easier to prevent severe deformity

Figure 8.25 Nebel's method of applying a corrective body jacket in recumbency. From Schulthess, "Die Pathologie und Therapie der Ruckgratsverkrummungen," 1:1052.

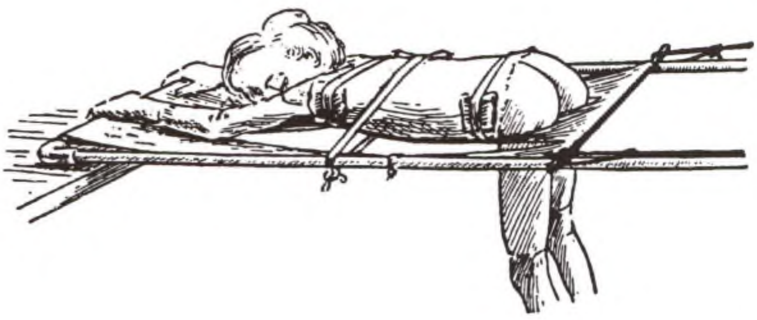
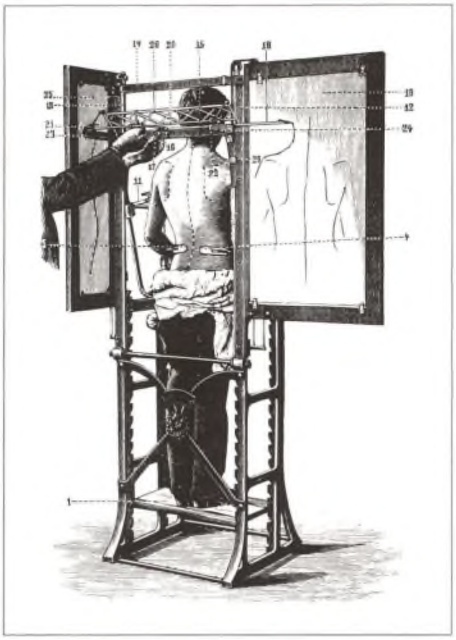
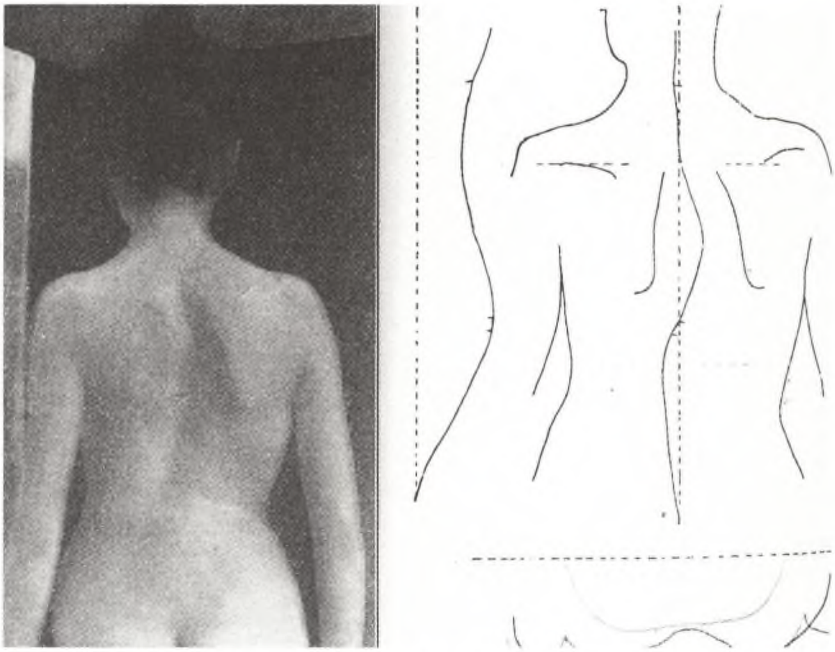


Figure 8.26 Lovett's method of applying longitudinal and lateral traction in recumbency during the application of a body jacket. From Schulthess, "Die Pathologie und Therapie der Ruckgratsverkrummungen," 1:1052.

than to correct it. In 1931 Hibbs presented the results of spinal fusion for scoliosis in 360 patients, 44 percent of whom had had poliomyelitis.[40] He reported that there had been 427 operations in the 360 patients, with 7 deaths and only 15 pseudoarthroses. He believed that the best method of preoperative correction was the turn-buckle cast. This work, which Hibbs carried out at the New York Orthopaedic Dispensary and Hospital, altered the entire approach to the treatment of scoliosis.

Two of Hibbs's younger colleagues, Joseph C. Risser (b. 1892) and Albert B. Ferguson (1895–1976) made independent contributions to the treatment of scoliosis using the technology of X-rays. While X-rays of the spine were available to Schulthess in 1905, the films were small and difficult to obtain because of the long exposures involved (figure 8.29). Fifteen years later X-rays of the spine were still not of optimum quality (figure 8.30). The glass plates slowly gave way to cellulose nitrate film and then to cellulose acetate film. X-ray tubes, intensifying screens, and grids were improved. By 1930, better films that were safe and easy to handle were available. It was the study of many such films that led to the development of the Ferguson method of measuring the angulation of the deformity in scoliosis.[41] Ferguson and Risser were able to determine that the progression of the deformity stopped when growth of the vertebrae ceased, confirming an opinion that had been shared by many orthopedists for decades. Risser also described the importance of the union of the iliac apophysis as a sign that vertebral growth had ceased.[42] A second method of measuring the angulation of the deformity in scoliosis,





Figures 8.27–8.28 Top: the apparatus employed by Schulthess to record the scoliotic deformity. It should be noted that it was measured in both the posterior and lateral aspects. Bottom: a photograph of a patient and his record from the device. From Schulthess, "Die Pathologie und Therapie der Ruckgratsverkrummungen," I:582, I:864.

Figure 8.29 An X-ray of a spine with scoliosis taken before 1905. From Schulthess, "Die Pathologie und Therapie der Ruckgratsverkrummungen," 1:876.

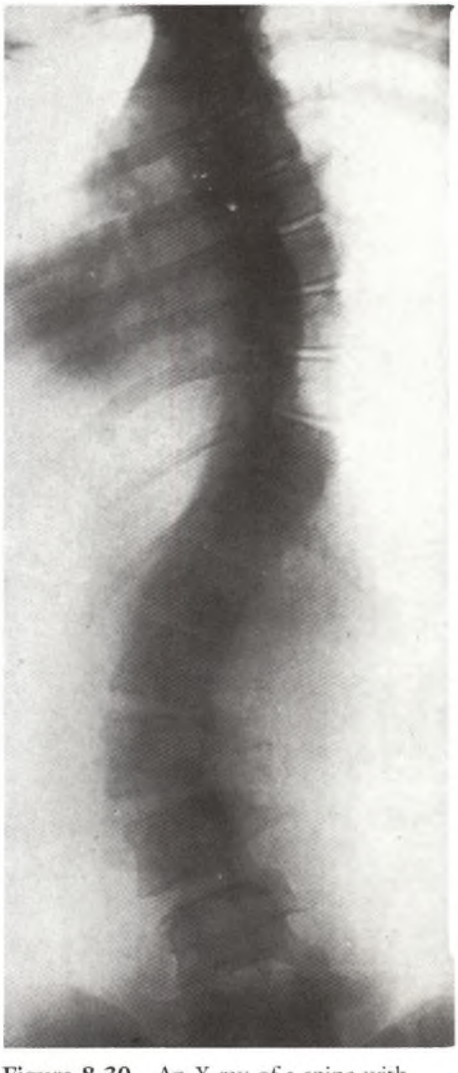


Figure 8.30 An X-ray of a spine with scoliosis taken in 1920. The amount of the spine included on the film has increased at the cost of definition. From F. H. Baetjer and C. A. Waters, *Injuries and Diseases of the Bones and Joints* (New York: Paul B. Hoeber, 1921), 294.

Figure 8.31 John R. Cobb (1903–1967). From Obituary: "John R. Cobb," *J Bone Joint Surg* 50A(1968): 1074.

Figure 8.32 Rudolf Klapp (1873–1949). From Bernhard Klapp, *Das Klapp'sche Kriechverfahren* (Stuttgart: Georg Thieme, 1955), frontispiece.

based on spinal X-rays, was developed by John R. Cobb (1903–1967) (figure 8.31) at the Hospital for the Ruptured and Crippled in New York City.[43] K. George and J. Rippstein compared the two methods of measurement and favored Ferguson's, although the Cobb method has been the most widely employed.[44] Cobb came from an old New England family and graduated from Brown University and the Yale Medical School. He joined the staff of the Hospital for the Ruptured and Crippled at the time Phillip D. Wilson was rejuvenating the staff with the appointment of a group of bright young men. Cobb was assigned the task of developing a clinic and a program for the treatment of patients with scoliosis. This became his life's work.

Arthur Steindler (1878–1959) in Iowa City studied scoliosis carefully and never became enthusiastic about spinal fusion. He developed a method of treatment based on compensatory curves. "This treatment simply advocates the reestablishment of compensation, which had been lost, by the development of compensatory curves of adequate degree to realign the body: shoulders square over pelvis, pelvis square over ankles."[45] The treatment consisted of programs of stretching and corrective bracing. Because of the emphasis on conservative treatment in his clinic and because conditions favored long follow-up periods, Steindler's associate Ignacio Posetti had the opportunity to carry out significant longitudinal studies of patients with scoliosis treated with and without spinal fusion.[46]

Another important nonoperative approach to the treatment of scoliosis at this time was that designed by Rudolf Klapp (1873–1949) (figure 8.32). Klapp was educated in Würzburg and then in Kiel, where he came under the influence of Auguste Bier, whom he followed to Berlin. Klapp developed a gymnastic program for the treatment of scoliosis called the *Kriechmethode* (crawling method), which stretched and strengthened the back muscles.[47] His techniques were demonstrated to sports medicine personnel attending the Olympics in Berlin in 1936.

At the beginning of World War II a committee of the American Orthopaedic Association, headed by A. R. Shands, Jr., investigated the status of the treatment of scoliosis in the United States to determine which course of treatment to recommend to its members. This committee reviewed the records of 425 patients and made some interesting observations.[48] The chief complaints of the patients were related to the cosmetic deformity. Exercise programs were able to maintain the status quo in only 40 percent of those treated in this manner; 60 per cent of the patients continued to have progressing deformity. Correction without fusion almost always failed to prevent progression of deformity. Only correction followed by fusion seemed to have lasting value. This report encouraged the operative approach to treatment of scoliosis.

Figure 8.33 Paul R. Harrington (1911–1980). Courtesy of the Paul R. Harrington Archives, Dept. of History and Philosophy of Medicine, University of Kansas Medical Center, Kansas City, Kansas.

At this time scoliosis complicating poliomyelitis formed an important segment of the general scoliotic population. The deformity was related to asymetrical paralysis of the trunk muscles and the severity to the age of onset and the extent of the muscle imbalance.[49] These patients, because of their often widespread truncal and limb paralysis, could not tolerate the corrective jackets required during preoperative and postoperative management. It was the challenge presented by such clinical problems that led to the development of spinal instrumentation.

Paul Randall Harrington (1911–1980) (figure 8.33) was born and raised in Kansas, played on championship basketball teams at the University of Kansas, and graduated from its college of medicine in 1939.[50] He finished his orthopedic training at the Dickson-Diveley Clinic in Kansas City, Missouri, in time to serve in World War II. Shortly after opening his practice in Houston in 1945, he found himself with the responsibility for the care of all of the poliomyelitis patients at the Jefferson Davis County Hospital.[51] The task was later shared between the Departments of Pediatrics and Orthopedics of the Baylor University College of Medicine. For the next ten years under continuing epidemic conditions, this unit received about three hundred new cases of poliomyelitis each year. A large number of these patients had truncal paralysis and progressing scoliosis with cardiopulmonary compromise. The usual methods of corrective casting and spinal fusion were inappropriate for this kind of patient. Harrington began attempts to apply internal fixation to the spine to fix the curves by transfixation of the vertebral facet joints with screws. This failed and was followed by attempts to use various combinations of rods and hooks. A grant from the National Foundation for Infantile Paralysis in 1954 allowed him to operate on fifty patients during the next five years, during which time the system of hooks and compression and distraction rods was designed and tested. The use of the technique was slowly extended to some patients with idiopathic scoliosis. In 1962 Harrington reported his results in the treatment of 129 patients cared for in the previous eight years.[52] After correcting the deformity intraoperatively, he performed a spinal fusion. Postoperatively the patient was supported in a plaster of paris jacket for several months. Eleven years later there was a second review of 578 patients.[53] By this time the method was well established and being used by orthopedic surgeons throughout the world. The technical armamentarium for the rodding has undergone continuous development and has reached a high degree of sophistication in the work of Y. Cotrel.[54] Spinal instrumentation, initially developed for a very special group of patients, has gained a very wide application in the treatment of all sorts of diseases and injuries of the spine.

The external skeletal fixation of the skull (the halo), was developed at the Rancho de Los Amigos in Los Angeles in response to

Figure 8.34 Walter P. Blount (1900–1992). From H. Mau, "Walter P. Blount zum 70. Geburtstag," *Zeit Orthop* 109(1970): 173.

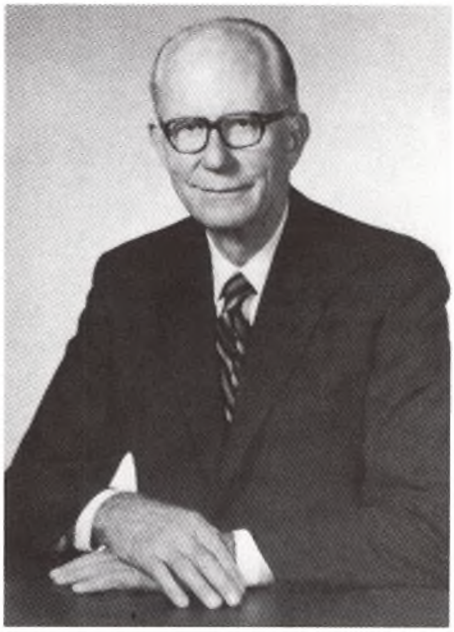


Figure 8.35 John H. Moe (1905–1989). From William J. Kane, "Newer Knowledge of Scoliosis: A Tribute to John H. Moe, M.D.," *Clin Orthop* 126(1977): 2–3.

the challenge of treating severely involved poliomyelitis patients with scoliosis.[55] Like spinal instrumentation, the halo has found wide application in the treatment of fractures and deformities. With the concept of spinal instrumentation established, it was not long before the anterior approach to the vertebral bodies was exploited for this purpose. A. F. Dwyer of Sidney Australia and his colleagues described a method of applying corrective forces intraoperatively by means of a cable passed through holes in the heads of screws attached to the vertebral bodies.[56] Through this same approach, Robert Roaf of Liverpool applied the principle of epiphyseodesis to the treatment of scoliosis and reported encouraging results.[57]

At the same time that surgical techniques for the treatment of scoliosis were being improved, there was a resurgence in the use of braces. Introduced in 1945 by Walter Blount (b. 1900) (figure 8.34) and Albert Schmidt, the Milwaukee brace proved to be a valuable adjunct in the treatment of scoliosis, both as a perioperative support and as a nonoperative treatment.[58] Blount attended the Illinois College of Medicine and the Rush Medical College in Chicago before joining the orthopedic practice of Frederick J. Gaenslen (1877–1937) in Milwaukee.[59] There he devoted himself to the treatment of crippled children. He described *osteochondritis deformans tibiae* (later named Erlacher-Blount syndrome), introduced epiphyseal stapling for the treatment of leg-length discrepancies, and made the phrase "fractures in children are different" orthopedic dogma.[60] His treatment of scoliosis patients with the Milwaukee brace was a major contribution. His collaborator in much of this work was his neighbor in Minneapolis, John H. Moe (1905–1989) (figure 8.35). Moe was born in rural North Dakota and attended the University of North Dakota.[61] He graduated from the Medical School of Northwestern University in 1929. The depression years and a bout with pulmonary tuberculosis complicated his orthopedic training, but he was able to establish an orthopedic practice in Minneapolis. He had his opportunity to become a specialist in scoliosis when he was offered the management of that service at the Gillette Hospital for Crippled Children in St. Paul, the first state-supported hospital for crippled children in the United States. There he perfected his technique for correction of the deformity with localizer casts and spinal fusion.[62] Moe became head of the Division of Orthopedic Surgery at the University of Minnesota in 1958. His private institute, the Twin Cities Scoliosis Center, was founded in 1964. His greatest contribution to the treatment of scoliosis was his role in founding the Scoliosis Research Society, of which he was the first president in 1966. This organization was important because although scoliosis had been investigated for years, the results of the research had not been very fruitful.[63]

The number of patients with scoliosis has been reduced substantially by the immunization programs for poliomyelitis. Screening programs for adolescent girls carried out in school systems have resulted in the detection of cases before severe deformity has developed.[64] Such cases have been treated conservatively with suitable braces.[65] More recently, the use of continuous electrical stimulation of the paraspinal musculature to prevent progression or to correct the deformity has been introduced by Walter P. Bobechko of Toronto.[66] Operative management of scoliosis is now limited to the complex and severe deformities.

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CHAPTER NINE

Neurological Disease

ORTHOPEDIC SURGERY was not the only specialty differentiating from the body of general medicine in the nineteenth century. Neurology was another and those who studied this area made many contributions to the specialty of orthopedics. One of the founders of neurology was Jean Marie Charcot[1] (1825–1893) (figure 9.1). Charcot was born in Paris, the son of a carriage maker. After a typical progression through the educational system, he obtained his degree in 1853 after defending a thesis devoted to differentiating the symptoms and lesions of gout from those of rheumatoid arthritis.[2] He remained in the academic mainstream, taking various competitive examinations and moving up the academic ladder until in 1862 he became the chief of medicine at the l'Hospice de la Salpêtrière, a hospital for chronic diseases that had five thousand patients. It was from the study of these patients that he made his important contributions to medicine and neurology.

Even before his appointment to the Salpêtrière, Charcot had already written the first description of intermittent claudication in man due to arterial insufficiency, a condition that had been described previously as occurring in horses.[3] His patient had suffered an occlusion of the internal iliac artery as a result of complications from a bullet wound.

The circulation was re-established by collateral channels, and the arterioles, which in their normal state are very small, became dilated so that the blood supply was sufficient when the patient was at rest, but when the limbs were fatigued by walking, the blood supply was inadequate; there is in this case a relative ischemia that causes numbness, cramps, and an incapacity for sustained walking.[4]

Figure 9.1 Jean Marie Charcot (1825–1893). From G. Guillain, *J.-M. Charcot 1825–1893, His Life-His Work* (New York: Paul B. Hoeber, Inc., 1959), frontispiece.

Tertiary syphilis of the spinal cord, or *tabes dorsalis*, produced a symptom complex that was called *locomotor ataxia*. Charcot was the first to describe the arthropathies associated with this condition, neuropathic arthropathies that have since been referred to as *Charcot joints.*

The clinical manifestations of these arthropathies are unique: There is a sudden onset of a generalized tumefaction of the limb; rapid changes in the articular surfaces of the joint which manifest themselves as crepitations that are often noticed a few days after the onset, their appearance being evidently determined by the duration

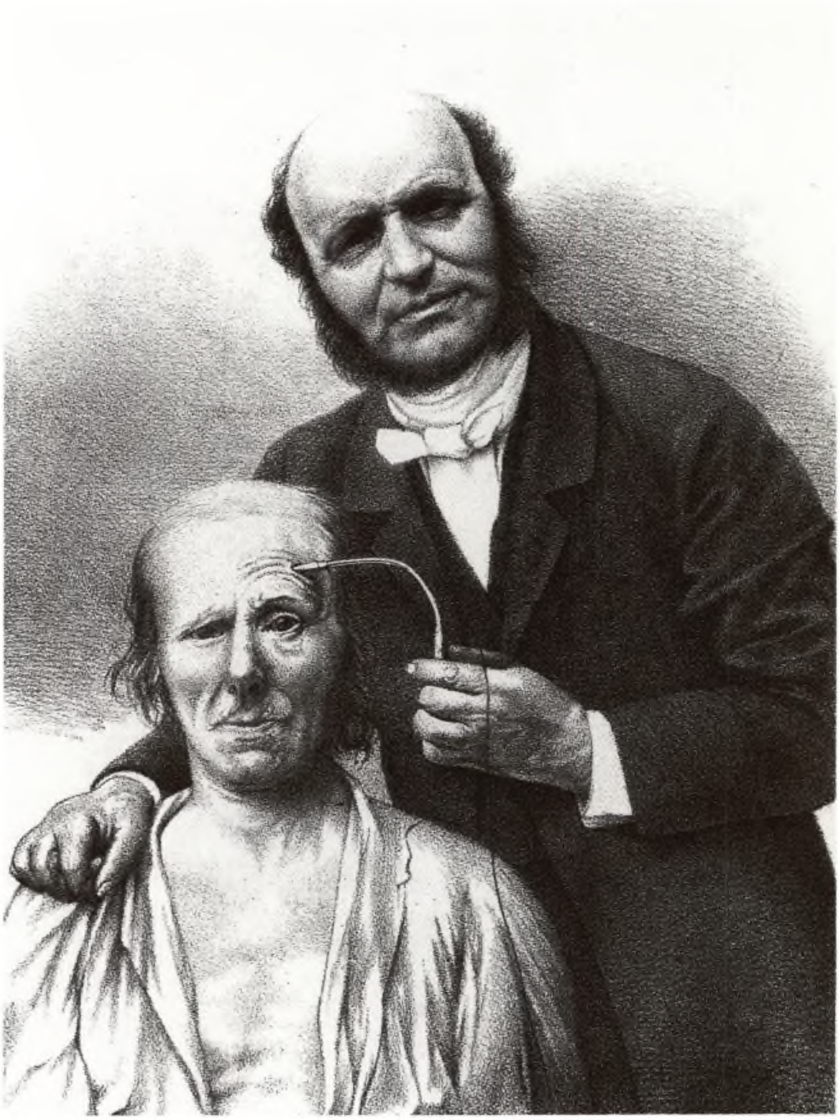

Figure 9.2 Guillaume Benjamin Amand Duchenne de Boulogne (1806–1875) with one of his patients. From *Selections from the Clinical Works of Dr. Duchenne (de Boulogne)*, trans. G. V. Poore (London: New Sydenham Society, 1883), frontispiece.

of the spinal cord disease; and they usually precede the development of the characteristic motor inco-ordination of tabes. These arthropathies develop without apparent cause; they do not result exclusively, as has been claimed, from the distention undergone by the ligaments and capsules of the joints or from the awkward gaits characteristic of ataxic patients, because they are frequently located in the upper extremities or they may involve the shoulder or the elbow. Moreover, they can develop in patients who show no sign of motor incoordination. Anatomically the enormous wear and tear shown by the heads of the bones, the extensive looseness of the ligaments of the joints, and the frequent occurrence of luxations seem to distinguish these arthropathies from the ordinary type of osteoarthritis.[5]

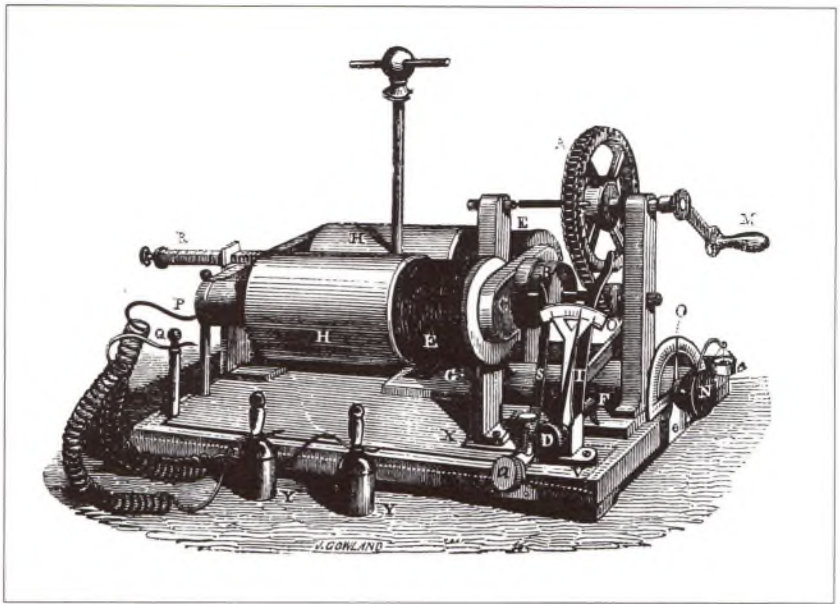

Figure 9.3 One of the hand-cranked generators designed by Duchenne for the electrical stimulation of his patients. From Duchenne, *De l'Électrisation localisée* (Paris: J. B. Baillière, 1855), 152.

Charcot observed that lesions in the spinal cord were associated with such arthropathies and established their neuropathic etiology.

In addition to his description of amyotrophic lateral sclerosis, Charcot, in collaboration with his pupil Pierre Marie (1853–1940), also described peroneal muscular atrophy in 1886.[6] This disease was also described by Howard Henry Tooth (1856–1926) of London in the same year.[7] This was one of the first examples of a familial-hereditary neurologic disease to be delineated.

Charcot was greatly influenced in his work by his association and close personal friendship with Guillaume Benjamin Amand Duchenne de Boulogne (1806–1875) (figure 9.2). Duchenne was born in Boulogne into a family of sea-going traders.[8] His father was decorated with the Cross of the Legion of Honor for valor as a ship captain during the Napoleonic wars. After a preliminary education at Douai, Duchenne studied medicine in Paris from 1826 to 1831, returning to practice in Boulogne. During this period he became interested in the medical uses of electricity and improved the usual method of electropuncture by covering the electrodes with moistened sponges and making the procedure noninvasive and less painful. He called his method of electrical stimulation *faradization* after Michael Faraday, the inventor of the induction coil (figure 9.3). Armed with this equipment he began his investigations on the effects of the electrical excitation of muscle.

After his wife's death in childbirth, Duchenne left Boulogne for Paris, where he established a small practice and became a familiar figure on the hospital wards of the Parisian hospitals. After convincing his colleagues that he had no interest in stealing their

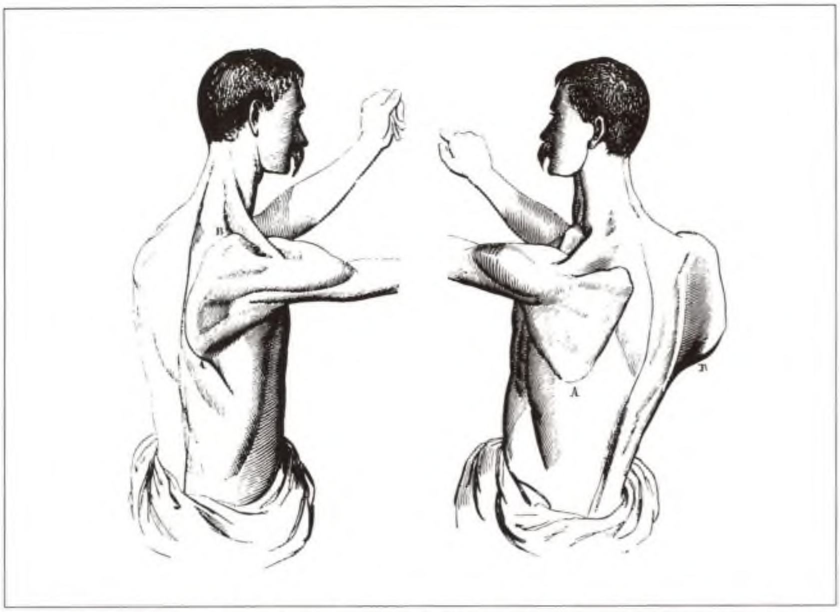

Figure 9.4 One of Duchenne's patients, illustrating how the atrophy allowed him to study the function of individual muscles. From Duchenne, *De l'Électrisation localisée*, 327.

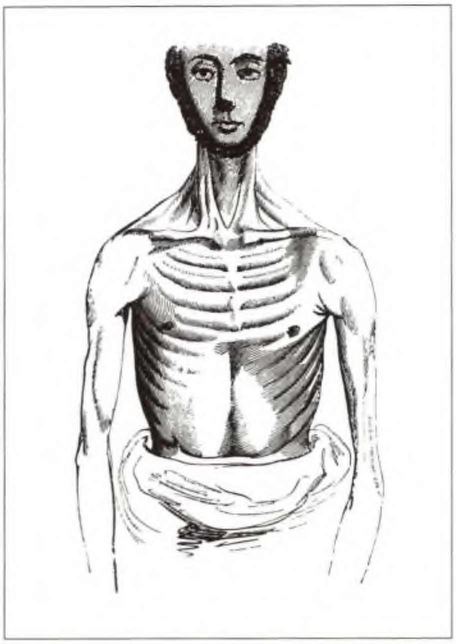

Figure 9.5 Another of Duchenne's patients, showing advanced muscle atrophy. From Duchenne, *De l'Électrisation localisée*, 288.

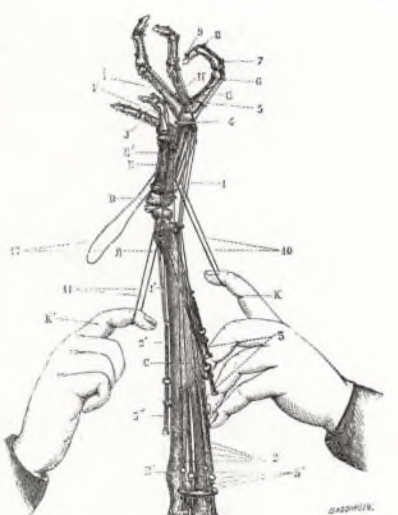

Figure 9.6 Duchenne's method of studying the function and balance of muscle strength in the forearm. From Duchenne, *Physiologie des mouvements* (Paris: J. B. Baillière et Fils, 1867), 267.

cases, he gradually was able to study a large number of patients with a wide variety of neurological problems (figures 9.4–9.5). He carried out longitudinal studies, following some patients from hospital to hospital for years until they died and were autopsied. As a result of this work he published two substantial monographs. *De l'Électrisation localisée* was published in 1855 and contained an account of his methodology and descriptions of many types of conditions, including poliomyelitis, progressive muscular atrophy and dystrophy, and locomotor ataxia.[9] *Physiologie des mouvements* was published in 1867 and was a great compendium of useful observations, some of which laid the foundation for the study of kinesiology[10] (figure 9.6).

Arthur Keith considered one of Duchenne's greatest observations as the discovery and elucidation of proprioceptive sensation in muscles and in joints, which he worked out in his studies of locomotor ataxia (*tabes dorsalis*).[11] This discovery led Charcot to the understanding of the neuropathic joint. In 1837 Charles Bell (1774–1842) recognized a "muscular sense" and in his treatise on the hand commented upon it.

> *The capacity, therefore, which the hand enjoys of ascertaining the distance, the size, the weight, the form, the hardness or softness, the roughness or smoothness of objects, results from its having a compound function — from the sensibility of the proper organ of touch, being combined with the consciousness of the motion of the arm, hand and fingers.*[12]

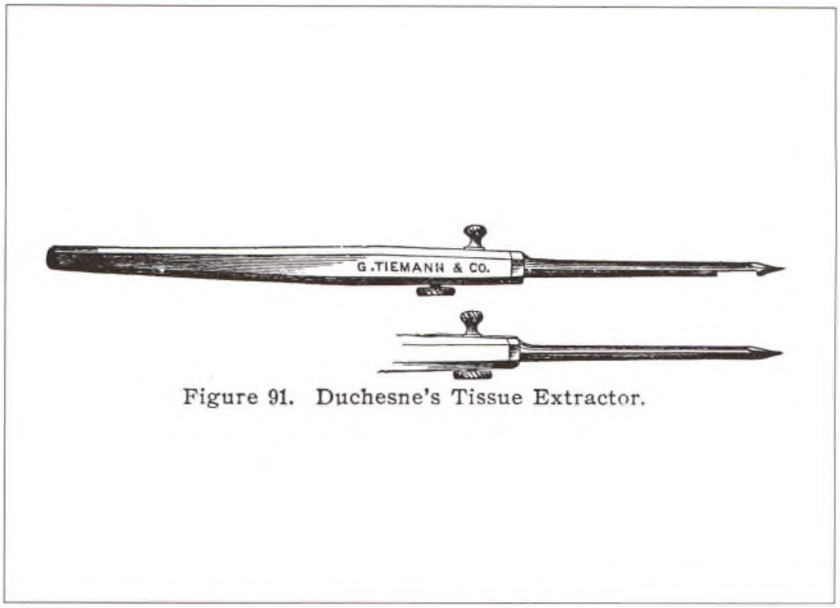

Figure 9.8 An advertisement for the instrument designed by Duchenne for muscle biopsy. Note the misspelling of his name. From Charles Truax, *The Mechanics of Surgery* (Chicago: Hammond Press, 1899), 67.

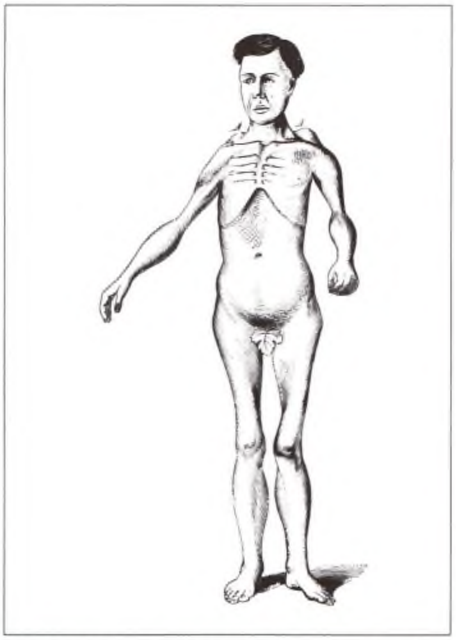

Figure 9.7 A patient with pseudohypertrophic muscular dystrophy. From Duchenne, *De l'Électrisation localisée*, 328.

Charcot appointed Duchenne to his service at the Salpêtrière in 1862 and gave him the facilities he needed for his investigations. Charcot also interested Duchenne in the new techniques of microscopic pathology. Duchenne became impatient waiting for autopsy findings and when he heard that Theodor Billroth had carried out an open biopsy to obtain tissue from a patient with pseudohypertrophic muscular dystrophy, he perfected the needle biopsy (figures 9.7–9.8).

I have devised a little instrument which I have named the "tis punch" [emporte pièce histologique] *by means of which, with very little pain, I have removed minute portions from the deep parts of muscles. It has been of great use to me for many years, and has never caused any serious trouble. Thanks to this instrument I have been able to complete my clinical observations by researches into the pathological condition of muscles of living patients.*[13]

Duchenne's use of his "histological harpoon" caused a stir in the lay press regarding the morality of examining tissue from the living body.[14] Duchenne also developed improved techniques for sectioning tissue for the preparation of microscopic slides.

Another example of Duchenne's ingenious application of his observations to the treatment of his patients were his muscular prostheses.

My object is to introduce into practice a system of apparatus destined, 1. To supply as far as possible the individual voluntary power of wasted or palsied muscles by re-establishing or helping natural movements; 2. To prevent or overcome deformities of joints by equal-

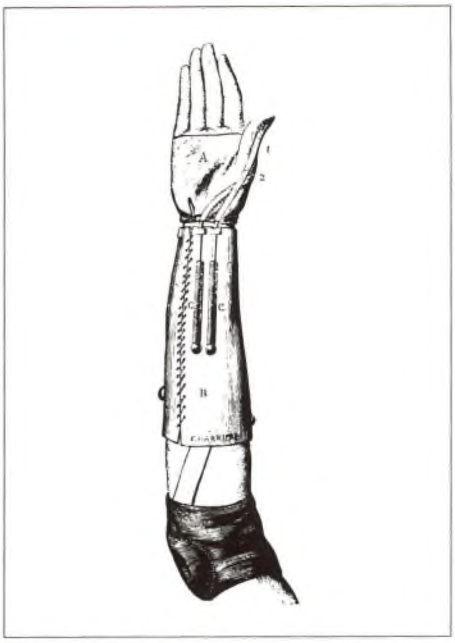

Figure 9.9 One of Duchenne's dynamic hand splints utilizing rubber bands to replace the *opponens pollicis.* From Duchenne, *Physiologie des mouvements,* 244.

izing the tonic forces which naturally control the relations of the articular surfaces. This method is physiological, because it imitates nature in disposing its artificial muscles according to the exact facts of anatomy and physiology[15] [figure 9.9].

His prostheses, like the dynamic hand splints of today, were powered by elastic bands.

Duchenne has been often thought of as a lonely widower, walking the wards of the Parisian hospitals "*avec sa pile et sa bobine*" (with his battery and his induction coil), cut off from the medical life going on around him. This was far from the case. His son became a physician and studied neurology with him from 1862 until his untimely death in 1871 from typhoid fever, and Duchenne's second wife, an English woman, entertained his medical colleagues frequently in their home and took Duchenne out into society.[16]

Duchenne's work on the muscular dystrophies was closely followed by his English colleagues. In a lecture delivered at the National Hospital for the Paralyzed and Epileptic in London in 1902, William R. Gowers (1845–1915) described a case of the pseudo-hypertrophic form in a boy of seven.

In this child no muscles are sufficiently increased in size to attract much attention, but the calves are distinctly large and firm. The knee-jerks are slight, but are not lost, as they are in the later stage of the disease. He is just acquiring the characteristic method of getting up from the floor, aiding the extension of the knees by putting his hands on them. This transfers some of the weight of the trunk from the upper end of the femur to its lower end, from the place at which the power exerted by the rectus acts to least advantage, to the place near the fulcrum at which the advantage is greatest. You may ask if this action is due to the weakness of the extensor of the knee, why is it characteristic of this disease, since these muscles are often weak from other causes? The question is a reasonable one. The action is not absolutely characteristic; it is met with in other maladies, but in such it is very rare. This particular method of aiding the defective movement seems to be acquired only when the weakness comes on slowly during the development of muscular ability. As a matter of fact it is so rare under other conditions that its diagnostic importance is very great.[17]

Gower's sign has remained an important observation in the diagnosis of muscular dystrophy.

In a discussion of the types of paralyses that followed injuries to mixed nerves and the effect of treatment of these paralyses by electrical stimulation, Duchenne gave a good description of birth palsies.

In short, certain violent manipulations of the midwife, necessitated by the difficulty of bringing down the arms after the birth of

Figure 9.10 Auguste Dejerine-Klumpke (1859–1927). From *Arch Neurol Psychiat* 20(1928): 193.

Figure 9.11 Heinrich Erb (1840–1921). From Webb Haymaker and Francis Schiller, *The Founders of Neurology*, 2d ed. (Springfield, Ill.: Charles C Thomas Pub., Inc., 1970), 436. Courtesy of Charles C Thomas Pub., Inc., Springfield, Illinois.

the trunk, or the strong pulling on the shoulder by a finger hooked round the arm-pit after the birth of the head, sometimes cause paralysis of the upper limb, seated in the deltoid, infraspinatus, and flexors of the elbow, characterised by falling of the limb alongside the trunk, inward rotation of the arm and extension of the elbow. The prognosis is usually grave. The paralysis may be cured by localised faradisation, but if left to itself it becomes incurable and causes wasting of the limb.[18]

Auguste Dejerine-Klumpke and Heinrich Erb provided more detailed descriptions of these brachial plexus injuries.

Madame Auguste Dejerine-Klumpke (1859–1927) (figure 9.10) was born in San Francisco and in early adolescence was taken to Switzerland with her three sisters to be educated.[19] Having decided to become a physician she went to Paris, where she managed to surmount all of the barriers placed in the way of women who wished to pursue a medical career. She became the first woman extern and intern in the Paris hospital system. Her paper on birth palsies was published very early in her career before her marriage to Jules Dejerine (1849–1917). Following their marriage the Dejerines formed a team and studied neurological problems together. Jules Dejerine became professor of neurology and chief at the Salpêtrière; Madame Dejerine-Klumpke became president of the Société de Neurologie and was an officer of the Legion of Honor. In addition to her work on birth palsies, she described the paraosteoarthropathies found in patients rendered paraplegic as a result of spinal cord injuries.[20]

Klumpke's paralysis is caused by a lesion of the lower trunk or medial cord of the brachial plexus, which results in wasting of all of the small muscles of the hand and then clawing of the hand. Fortunately, this most disabling of the birth palsies is the most infrequent. Dejerine-Klumpke noted that this condition could be associated with Horner's syndrome (constriction of the pupil and ptosis due to injury of the stellate ganglion). Erb's paralysis is caused by a lesion in the upper brachial plexus or the roots of the fifth and sixth cervical nerves. This results in paralysis of the muscles in the upper arm while the hand is spared. In his paper, Heinrich Erb (1840–1921) (figure 9.11) described four adults who had paralyses of deltoid, biceps, and brachialis muscles of uncertain etiology.[22] He localized the site of the neurological lesions in the upper portion of the brachial plexus. In his discussion he noted the similarity of his cases to those patients with birth palsies reported by Duchenne and commented that he had seen one such case. Erb's palsy is the most common form of birth palsy.

Erb was educated at Heidelberg, Erlangen, and Munich.[23] He returned to Heidelberg in 1867, where he became one of the founders of the specialty of neurology in Germany, participating in the description of many neurological diseases and syndromes. The most important of these was the demonstration of the syphilitic origin of *tabes dorsalis*. He was the first neurologist to utilize the reflex hammer.

The brachial plexus palsies described by Dejerine-Klumpke and Erb, as well as complete plexus paralysis, were caused by traction on the plexus during parturition, although a variety of other suggestions were made regarding their etiology.[24] J. W. Sever (1878–1964), working in the surgical pathology laboratory at Harvard, carried out experiments on newborn cadavers in which he demonstrated the maneuvers that produced both types of brachial plexus injury.[25] This type of traction injury to the nerve trunks was defined still further by the little known work of J. H. Stevens (1871–1932) of Boston, who carried out extensive study and dissections of the brachial plexus at Tufts and Harvard medical schools. The results of his investigations were published after Stevens's death by E. A. Codman in his book on the shoulder.[26]

The prognosis for the spontaneous recovery from nerve injury varied with the degree of damage and was better in upper plexus lesions than in lower plexus lesions. However, when recovery did not occur the deformity was characteristic: the arm hung dependant with the elbow extended, the forearm in pronation, and the whole arm internally rotated. Abduction and external rotation of the shoulder were limited severely. Based on his observations in the laboratory and in his patients, Sever designed an operation to improve the function of the arm that consisted of tenotomies of the tendons of the subscapularis and pectoralis muscles and occasionally the tendons of the coracobrachialis and short head of the biceps muscles.[27] This technique was modified by J. B. L'Episcopo, who added a transplantation of the attachment of the *teres major* and *latissimus dorsi* muscles posteriorly and laterally.[28] An osteotomy of the humerus above the level of the insertion of the deltoid muscle was also sometimes needed in order to obtain external rotation. The results of such operations have been presented by Jack Wickstrom.[29] While the incidence of birth injuries to the brachial plexus has decreased with improved obstetrical management, they remain an important problem.[30]

Birth palsies were not the only obstetrical complications that came to the attention of the orthopedic surgeons. William J. Little (1810–1894), the founder of the specialty in England, gave a paper to the Obstetrical Society of London in 1861 that described another complication of delivery. It's title, "On the Influence of Abnormal Parturition, Difficult Labours, Premature Birth, and Asphyxia Neonatorum, on the Mental and Physical Condition of the Child, Especially in Relation to Deformities," speaks for itself.[31]

The object of this communication is to show that the act of birth does occasionally imprint upon the nervous and muscular systems of the nascent infantile organism very serious and peculiar evils. When we investigate the evils in question, and their causative influences, we find that the same laws of pathology apply to diseases incidental to the act of birth as to those which originate before and after birth. We are, in fact, afforded another illustration that there exists no such thing as exceptional or special pathology.

Thirty-five years ago the pathology of deformities, if not invested with fable, was wrapped in obscurity; it was then scarcely perceived that the materials for extensive inductive observation existed.

Nearly twenty years ago, in a course of lectures published in the "Lancet" and more fully in a "Treatise on Deformities" published in 1853, I showed that premature birth, difficult labours, mechanical injuries during parturition to head and neck, where life had been saved, convulsions following the act of birth were apt to be succeeded by a determinate affection of the limbs of the child, which I designated spastic rigidity of the limbs of new-born children, spastic rigidity from asphyxia neonatorum, and assimilated it to the trismus nascentium and the universal spastic rigidity sometimes produced at later periods of existence.[32]

This long paper gives the details of sixty-three cases and contains some interesting observations.

The intellectual functions are sometimes quite unaffected, but in the majority of cases the intellect suffers — from the slightest impairment which the parent unwillingly acknowledges or fails to perceive up to entire imbecility.[33]

Little further observed that

as the child approaches the period at which the first attempts at standing and progression should be made, it is observed to make no use of the limbs, or he is incapable of standing except on the toes, or the feet are disposed to cross each other. Even children slightly affected rarely "go alone" before three or four years of age, many are unable to raise themselves from the ground at that age, and others do not walk, even indifferently, at puberty. On examination, the surgeon finds that the soles of the feet are not properly applied to the ground, that the knees always incline inwardly, and continue bent. When locomotion is accomplished, the movements are characterised by inability to stand still and balance the body in erect attitude. In the best recoveries from general spastic rigidity, even in the adult, the gait is shuffling, stiff; each knee, by forcible spastic rubbing against its fellow, obstructs progression[34] [figure 9.12].

Little classified the various manifestations of this condition as (1) hemiplegia with rigidity, (2) paraplegia with rigidity, (3) generalized rigidity, and (4) disordered movements without rigidity.

Figure 9.12 A case of spastic hemiplegia. From W. J. Little, "On the Influence of Abnormal Parturition," *Trans Obstet Soc London* 3(1862): 293–344, pl. 7.

In the discussion following the paper, the obstetricians to whom it was addressed expressed little knowledge of this complication, one even stating the opinion that dentition was the greatest source of paraplegia and hemiplegia in young children.[35] Little himself, in the absence of any descriptions of the problem in English, was forced to call upon Shakspeare's delineation of Richard III for an example (*see* chapter 1).

The term *athetosis* was first used in 1871 by William Alexander Hammond (1828–1900), a neurologist in New York, to describe another manifestation of cerebral palsy.[36] Prior to settling in New York immediately after the Civil War, Hammond had been an army surgeon in the West during the Indian wars and had en-

Figure. 9.13 Winthrop M. Phelps (1894–1971). From *Develop Med Child Neur* 14(1972): 265.

dured a stormy tour of duty as the surgeon general of the army between 1862 and 1864. He should be remembered as the founder of the Army Medical Museum, which has grown to become the Armed Forces Institute of Pathology. He was one of the founders of the specialty of neurology in the United States.

Thirty-five years passed before another classification of cerebral palsy was proposed, this one by a young Viennese physician interested in pediatric neurology. Sigmund Freud (1856–1939) had visited Charcot's clinic in Paris on a travelling fellowship in 1885–86.[37] His work on the cerebral palsies of children was the direct result of this influence. In a paper published in 1893, Freud grouped these conditions into two groups, hemiplegias and diplegias, characterized by general rigidity, paraplegic rigidity, bilateral hemiplegia, generalized chorea, and double athetosis.[38] This classification has been used in one form or another for almost one hundred years. He also made the important observation that there was a very poor correlation between the clinical syndromes and the neurologic lesions found in the brain.

Early in his career William Osler (1849–1919) had also become interested enough in the problem of cerebral palsy to write a series of articles about it, which were gathered together and published as a monograph in 1888.[39] This work was based upon the observation of a large number of patients seen at the Infirmary for Nervous Diseases in Philadelphia. Both Freud and Osler soon lost interest in the subject of the cerebral palsies and went on to success in other areas of medicine. However, their observations on cerebral palsy were of significant value.

Orthopedic surgeons could not abandon the treatment of the problems presented by the patients with cerebral palsy, especially in its spastic forms. They continued to try to improve the lot of these unfortunate patients and their families. When neglected, the deformities could become very severe. Louis Bauer was thinking of just such a patient when he wrote in 1868.

> *Some years ago a boy was brought to me who presented all these deformities* [flexion contractures] *collectively, and who was therefore unable to use any of his extremities. He represented a veritable bundle placed in the corner of my office.*[40]

Treatment consisted generally of some form of physical therapy, braces of various types, and tenotomies to relieve contractures.[41] In spite of the best of intentions, in most clinics there was a defeatist attitude regarding these patients and their care was given a low priority in comparison to children crippled by poliomyelitis and congenital deformities.

In 1932 children with cerebral palsy found a champion in Winthrop M. Phelps (1894–1971) (figure 9.13). It was Phelps who established the principle that children with cerebral palsy could and should be helped to achieve their full potential as individuals.

Phelps attended Princeton University and graduated from Johns Hopkins Medical School in 1920. After postgraduate training in Boston, he joined the Yale University faculty in 1926. By 1931 he had become chairman of the Department of Orthopedics. His increasing interest in the problems of cerebral palsy patients led him in 1936 to resign his academic position and move to Baltimore, where he established the Childrens's Rehabilitation Institute. He remained associated with this institution for the rest of his career. As a founding member of the American Academy of Cerebral Palsy and through his work at the institute, he had a great influence in bringing the problems of these patients to the attention of the orthopedic community. He emphasized a holistic approach, looking at each individual as a whole person, rather than concentrating on specific mechanical or neurological deficiences. One of his early papers entitled "Cerebral Birth Injuries: Their Orthopaedic Classification and Subsequent Treatment," was considered by Edgar M. Bick to be the most important publication on the subject since Little's original description of cerebral palsy.[42]

Another founding member of the American Academy for Cerebral Palsy was Temple Fay (1895–1963) of Philadelphia.[43] Fay was a neurosurgeon and did important work on the medical use of hypothermia in patients. In 1943 he gave up his position at Temple University, where he had been professor and head of the Department of Neurosurgery, to establish the Neuro-Physical Rehabilitation Clinic for the treatment of patients with cerebral palsy. As a result of his study of patients with cerebral palsy, he laid the theoretical basis for a treatment program based on progression and pattern movements. This system became known as the Doman-Delacato Treatment Procedures, named for two of Fay's associates, Glenn J. Doman, a physical therapist, and Carl H. Delacato, a psychologist. This system is just one of many treatment programs for cerebral palsy patients that have been developed, each of which has had its fervent advocates.[44]

At the same time that orthopedic surgeons were attempting to deal with the consequences of a condition caused by poorly localized, diffuse brain damage, they also were learning how to diagnose and treat a highly specific and well-localized condition affecting spinal nerve roots. The term *sciatic* is derived from the Greek word for the hip joint, *ischion*, and the sciatic nerve is, therefore, the nerve of the hip. *Sciatica*, also known as *ischialgia*, was well known to the ancients. Celsus referred to sciatica as *"coxae vero dolorum."*[45] In 1764 Domenico Cotugno (1736–1822) of Naples gave this description of the condition:

What one calls sciatica or ischias is well known to physicians: by this, one means a persistant pain in one hip, rarely in both, often *only in the level of the joint and then in the leg, which makes the patient lame on that side.*[46]

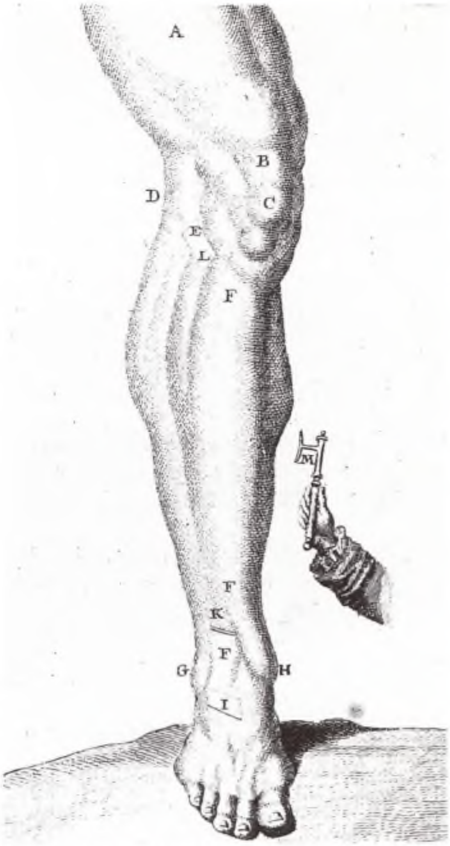

Figure 9.14 Plate illustrating the course of the distal branches of the sciatic nerve as indicated by the letters. The hand-held instrument is a cautery for blistering, a commonly used form of treatment. From D. Cotugno, *Abhandlung vom nervigen Hüftweh*, (Leipzig: Friederich Schneidern, 1792), facing p. 150.

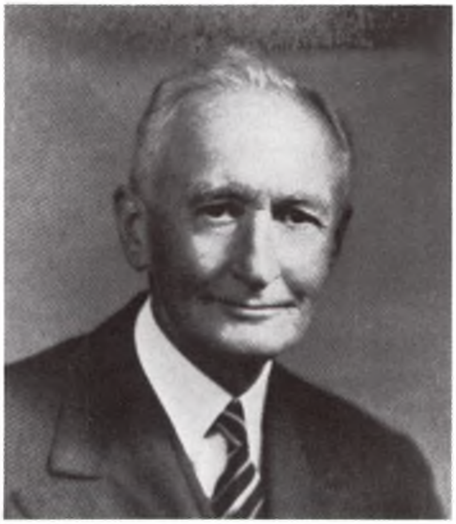

Figure 9.15 William Jason Mixter (1880–1958). From *Trans Am Surg Assoc* 76(1958): 452.

In his book, Cotugno differentiated between pain in the distribution of the femoral nerve from pain in the sciatic nerve distribution[47] (figure 9.14). He lamented the fact that he had never been able to dissect a patient dying of the disease but believed that on clinical grounds the symptoms were due to an irritation of the sciatic nerve. This small monograph also contained the first good description of the cerebospinal fluid in the subarachnoid space about the spinal cord.

In 1864 Charles Ernest Lasegue (1816–1883), a French neurologist, wrote a long paper in which he discussed Cotugno's work thoroughly and reviewed the theories as to the cause of sciatica up to his time. Unfortunately Lasegue could add nothing new.[48] It was not until 1880 that one of Lasegue's students, J. J. Forst, described what we now call Lasegue's test: with the patient supine, when the straight leg is flexed at the hip as far as possible, dorsiflexion of the ankle that causes pain or muscle spasm in the hamstring muscles indicates lumbar root or sciatic nerve irritation.[49]

While neurologists were making progress in diagnosis, pathologists and surgeons were stumbling over their observations of displaced and herniated discs, not recognizing them for what they were and failing to make the connection between their findings and the clinical syndrome of sciatica.[50] It was not until 1929 that Walter E. Dandy (1886–1946) of Johns Hopkins Hospital demonstrated in two patients that masses of discal origin could produce sciatica and that their removal would result in a cure.[51] His report caused little comment because neither of the two patients presented a classic history for sciatica. In addition, the title of his article, "Loose Cartilage from Intervertebral Disk Simulating Tumor of the Spinal Cord," led readers to focus on the word tumor and thus they failed to make the important association between disc protrusion and sciatica. Five years later William J. Mixter (1880–1958) (figure 9.15) and Joseph S. Barr (1901–1964) (figure 9.16) published their paper, "Rupture of the Intervertebral Disc with Involvement of the Spinal Cord," which established the role of the ruptured disc in the etiology of sciatica.[52] In concluding the discussion of this paper, which was presented at the annual meeting of the New England Surgical Society, Mixture sounded this note of caution:

There have been two or three cases which I have operated on expecting to find the lesion and in which I have had a negative exploration, and those we have not included in this presentation today because it seemed to us to confuse the picture. It is a difficult diagnosis to make and we have been wrong several times.

Once neurosurgeons and orthopedists became aware of the cause of the syndrome and its surgical treatment, operations for "disc" became commonplace.

Mixture was a graduate of the Massachusetts Institute of Technology and Harvard Medical School.[53] After a year of internship he joined his father and brother in private practice in Boston. A long-developing interest in surgery of the nervous system led him to specialize in this field and in 1926 he became head of the newly established neurosurgical service at the Massachusetts General Hospital. He served in France during World War I and as a senior consultant to the surgeon general of the army during World War II. In contrast to Harvey Cushing (1869–1939), whose neurosurgical interests were confined to the brain, Mixture's surgical practice also included surgery of the spinal cord and sympathetic nervous system.

Figure 9.16 Joseph Seaton Barr (1901–1964). From *J Bone Joint Surg* 47A(1965): 1146.

Barr was a graduate of Wooster College in Ohio and from the Harvard Medical College.[54] After his postgraduate training in Boston, he was asked to join the practice of his professor, Frank R. Ober. He rapidly established himself in the academic world. From 1948 until 1964 he was the John B. and Buckminster Brown Professor of Orthopaedic Surgery at Harvard. Barr has left a charming account of his involvement in the first operations for disc disease.[55] He pointed out that he and his colleagues might have fallen into the same error as their predecessors if he had not been involved at the time with the review of the German monograph on the spine by G. Schmorl and H. Junghans.[56]

Hand-in-hand with the development of surgical techniques came developments in diagnostic radiology. Myelography was described by Jean Athanese Sicard (1872–1929) and Jacques Forestier (1890–1978) in 1921.[57] Lipiodol was the contrast material used and it caused many complications. The introduction of less dangerous materials increased the value of this technique. The injection of radio-opaque material directly into the disc (discography), was described by Kurt Lindblom in Sweden in 1948.[58] The use of this diagnostic method led Lyman Smith (1912–1991) (figure 9.17) to introduce a most interesting method of treatment of the damaged disc by means of the injection of an enzyme, chymopapain, into the disc space. Smith was born in Cleveland and educated in Chicago. After graduating from Northwestern University Medical School he had further postgraduate training in Chicago and Boston before opening his practice in the suburban Chicago area. Following distinguished service in the navy in the South Pacific during World War II, he returned to his practice and an appointment to the orthopedic faculty of his alma mater. In spite of being completely involved with his private practice, his inquisitive and innovative mind led him to consider new ideas and methods. He was one of the first to study use of ceramic materials as

Figure 9.17 Lyman Smith (1912–1991). Courtesy of the International Intradiscal Therapy Society, Grays Lake, IL.

bone substitutes.[59] He became best known for his work with the injection of chymopapain into the disc space as a method of treating disc disease.[60] In his clinical trials he was aided by his colleague J. E. Brown (b. 1915) of Cleveland. After an enormous amount of opposition, particularly from the neurosurgical community, Smith finally established his procedure as a useful alternative to surgical intervention in properly selected patients.

During the emergence of the specialties of neurology, neurosurgery, and orthopedic surgery there was a great deal of cross fertilization, with each group contributing significantly to the development of the other, illustrating why no specialty can survive and grow in isolation from the mainstream of medicine.

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CHAPTER TEN

Chronic Affections of the Joints

THE STUDY OF CHRONIC affections of the joints has been complicated by the large number of heterogeneous diseases making up this category and the extensive confusing and overlapping terminology applied to them. For example, the twenty-fifth edition of *Stedman's Medical Dictionary*, published in 1990, defined arthritis as follows: "arthritis, pl. arthritides: articular rheumatism; inflammation of a joint or a state characterized by inflammation of the joints."[1] This definition was then followed by a list of twenty-five entries, the most recent of which was Lyme arthritis, the joint manifestations of Lyme disease.

In presenting the historical background of the rheumatic diseases, J. T. Scott has pointed out the importance of the work of Guillaume de Ballou (1538–1616), a contemporary of Ambroise Paré, who first used the term *rheumatism* in its modern sense, and Thomas Sydenham (1624–1689), the "English Hippocrates," who first clearly differentiated gout from rheumatism.[2] The regimen prescribed by the papal physician Jacopo Bonacossa (1483–1553) for Pope Paul III contained the opinions regarding treatment held by the ancients as interpreted by the physicians of the Renaissance.[3] The clinicians of the nineteenth century were well acquainted with the various stigmata of arthritis (figure 10.1).

Arthritis as a complication of gonorrheal infection was described as early as 1664 by Pierre Martin de La Martinière[4] (1634–1690). The arthritis associated with congenital syphilis, however, was not identified until 1886, when H. H. Clutton's (1850–1909) paper, "Symmetrical Synovitis of the Knee in Hereditary Syphilis," was published in the *Lancet*.

The average age of the patients recorded in the accompanying table was about thirteen, but they were mostly between the ages of eight

Figure 10.1 Drawings by J.-M. Charcot illustrating a hand with a gouty tophus, a hand deformed by rheumatoid arthritis, and the gross pathology of a Heberden's node. From W. S. C. Copeman, *A Short History of Gout* (Berkeley: Univ. of California Press, 1964).

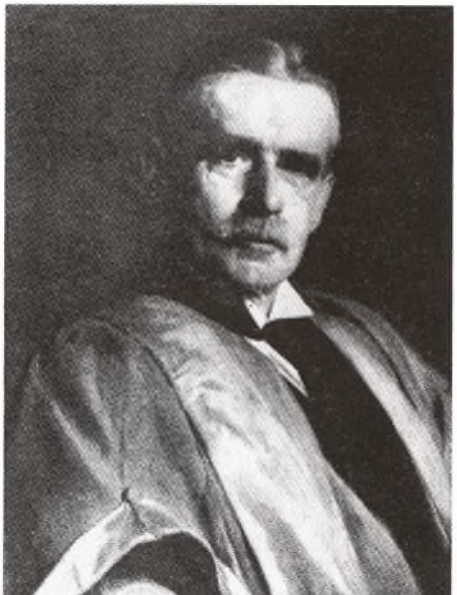

Figure 10.2 George Frederic Still (1868–1941). From *J Ped* 49(1956): 229.

and fifteen. The predominate features of the disease were the symmetry of the affection, the freedom from pain, the long duration of the symptoms and the free mobility of the joints on passive movement throughout the course of the disease. Its symmetrical character first led me to look for a constitutional cause, and there was no difficulty in seeing that the patients were the subjects of hereditary syphilis. I do not mean to say that no other constitutional disease could possibly have produced such a symmetrical condition, but I do think that other joints besides the knees would probably have been at some time and in some of the cases affected in a similar manner if such diseases as rheumatism, gonnorrhoea, or [*sic*] *gout had been the cause. I have never seen both knee-joints fill with fluid, causing scarcely any pain or discomfort, whilst other joints remain quite free from any signs of inflammation, except in cases where there was distinct evidence, either past or present, of hereditary syphilis.*[5]

The most frequent manifestations of congenital syphilis found in patients with Cluttons's knees were keratitis and Hutchinson's teeth.[6] Clutton was a distinguished surgeon at St. Thomas's Hospital, London. He was an early proponent of aseptic surgical technique, and one of the first to use a cap, mask, and gloves in the operating room.[7]

Ten years after Clutton's description of his syndrome, another form of chronic joint disease in children was described by George F. Still (1868–1941) (figure 10.2). Still was born in a working-class suburb of London. Through his own drive and ability, he was able to obtain an education.[8] At Cambridge he took a first in classics. Trained at Guy's Hospital, he gained an appointment at the Hospital for Sick Children, Great Ormond Street, where he remained for over thirty years. Still was the first physician in England to limit his practice to diseases of children and should be considered as the founder of the specialty of pediatrics in England. He developed an extensive practice, which included the children of the royal family. His report, published when he was only a registrar, was based on the observation of twenty-two cases.

There is a disease, occurring in children, and beginning before the second dentition, which is characterized clinically by elastic fusiform enlargement of joints without bony change, and also by enlargement of glands and spleen.

This disease has hitherto been called rheumatoid arthritis, but it differs from that disease in adults, clinically in the absence of bony change, even when the disease is advanced, and in the enlargement of glands and spleen, and pathologically in the absence, even in an advanced case, of the cartilage changes which are found quite early in that disease, and also in the absence of osteophytic change.

These differences are not to be attributed merely to modification of disease by difference of age, as there occurs also in children a disease in every respect identical with the rheumatoid arthritis of adults.[9]

A somewhat similar syndrome occurring in adults, characterized by arthritis, splenomegaly, and leucopenia, was described by A. R. Felty (b. 1895) in 1924.[10]

Ankylosing spondylitis was described just prior to the end of the nineteenth century by V. M. Bechterew, Pierre Marie, Adolf Strumpell and Joel Goldthwaite.[11] The papers of Marie and Goldthwaite were the most complete. During this century the large number of arthritic syndromes was augmented continuously by the recognition of new varieties. In spite of this, the treatment of patients with arthritis did not have a high priority. Prior to the beginning of the twentieth century the treatment of osteoarthritis received little attention. For example, in a textbook of 650 pages published in 1901, Royal Whitman (1857–1946) devoted barely a page to the discussion of osteoarthritis of the hip.[12]

While their medical colleagues were defining the multiple syndromes that resulted in loss of function in the joints on the basis of their clinical appearance, pathological changes, and the chemical imbalance present, as in the case of gout, orthopedic surgeons were approaching the treatment of these patients pragmatically with operations to correct deformity and improve function. Richard Barwell (1826–1916), a London surgeon, in his book on joint diseases published in 1881, described the methods of treatment to be employed when the joint was not completely stiff.

Leaving for the present, true anchylosis to be dealt with hereafter, we will consider the means at our disposal for treating the other forms of joint stiffness. These are, 1, sudden force; 2, gradual force; 3 division of extra-articular impediments. This last is not unfrequently to be combined with the other two devices. At the present day the use of gradual extension is almost abandoned, or is used only as an adjuvant to sudden force; because it is very slow, often painful, and also uncertain. Forcible rupture, or rapid extension of false anchylosis, or peri-synovial impediments, could only attain its present development since the invention of anaesthetics; not merely because by their means pain is avoided, but also because they eliminate both voluntary and emotional muscular contraction, thus preventing serious injuries, which otherwise are likely to result.[13]

In patients with true anchylosis, or solid fusion of the joint, Barwell relied on osteotomy to correct deformity. The first such osteotomy had been done by John Rhea Barton (1794–1871) of Philadelphia in 1837.[14] Gurdon Buck (1807–1877) of New York followed Barton's example eight years later in 1845 when he performed osteotomies of the distal femur and proximal tibia to cor-

Figure 10.3 Illustration of Gurdon Buck's patient following osteotomy. Notice the *patten*, or shoe lift, under the left shoe. This drawing was made from a daguerreotype and, as such, was the first published clinical photograph. From "Selections from the Writings of Gurdon Buck," *Med Classics* 3(1939): 800.

rect a severe flexion deformity of the knee resulting from septic arthritis in a twenty-two-year-old farmer.[15] Buck's article was accompanied by a woodcut engraved from a daguerreotype of the patient, the first known clinical photograph to be published[16] (figure 10.3). Gurdon Buck was born and educated in New York City, graduating from the College of Physicians and Surgeons in 1830. He spent almost three years of postgraduate study in Berlin, Paris, and Vienna before returning to New York, where he had a distinguished career as a surgeon. His memory has been perpetuated by the eponyms *Buck's traction* and *Buck's fascia.*[17] These operations did not restore motion to the joints, but produced a limb with a stiff joint in a functional position. *Arthrodesis*, or joint fusion, had wide application in the treatment of tuberculosis, poliomyelitis, and other diseases of the joints. Its use for the treatment of osteoarthritic hip was advocated by some orthopedic surgeons until shortly before World War II.[18]

Osteotomy to correct deformities and preserve joint motion in patients with rickets and congenital dislocation of the hip was also used to correct deformities in patients with osteoarthritis of the hip.[19] T. P. McMurray (1888–1940) (figure 10.4) of Liverpool became the foremost advocate of such operations.[20] Born and educated in Belfast, McMurray graduated in medicine from Queen's University and then went to Liverpool to work with Robert Jones. During World War I, he was a part of the great orthopedic system organized by Jones, serving at Alder Hey Military Orthopaedic Hospital in Liverpool. Following the war he remained in Liverpool, and in 1938 became the first professor of orthopedics at the University of Liverpool. A good companion and a great teacher, he had many friends in the United States. In a paper on osteoarthritis of the hip joint read at the meeting of the American Orthopaedic Association in Atlantic City in 1938, McMurray discarded fusion as an option in treatment and instead described his displacement osteotomy.

The operation is performed with two objects in view: first, the transference of some of the body weight from the pelvis directly through the shaft of the femur, thus relieving the hip joint; and, second, the rotation of the head of the femur, so that in weight-bearing a new portion of the articular surface takes the remaining weight.[21]

Postoperatively the patient was immobilized in a plaster of paris spica. On the basis of his experience with forty-two patients over a period of ten years, he concluded that if the operation was carried out properly there was every expectation of relief from pain and preservation of a useful range of motion. The use of internal fixation made the confinement in a hip spica unnecessary and helped to popularized the operation. The results of the op-

Figure 10.4 Thomas Porter McMurray (1888–1949). From *J Bone Joint Surg* 31B(1949): 618.

eration were generally successful and the condition of the hips did not deteriorate with the passage of time.[22] As a result, it was the most commonly recommended operation for the treatment of osteoarthritis of the hip before the introduction of total hip replacement. As experience with hip operations accumulated it became more and more difficult to explain the result of the operation on the factors suggested by McMurray. It was not until studies were done on the venous circulation of the upper end of the femur in patients with osteoarthritis of the hip that the underlying physiologic process became clear. These studies demonstrated that severe venous congestion was present, which was relieved by osteotomy.[23] After some delay, operation of high tibial osteotomy was employed to correct deformity in patients with osteoarthritis of the knee. The results were strikingly similar to those of high femoral osteotomy.[24] The chief proponent of this operation in the United States was Mark Coventry of the Mayo Clinic.[25]

The first operation designed to produce a stable, moveable joint in a patient with a stiff hip was carried out by John Rhea Barton.[26] Barton was born, raised, and educated in Philadelphia, where he had a distinguished career as a surgeon. While he did not publish many papers, his observations on bending fractures of the forearm in children and on fracture dislocations of the wrist (Barton's fracture), were important.[27] His conception of an operation to restore motion to a fused hip joint was brilliant.[28] His patient was a twenty-one-year-old sailor who had been injured in a fall on shipboard in which he sustained an injury to the right hip. The hip became stiff in a position of flexion and adduction. Barton reasoned that if he divided the bone and persisted in moving the osteotomy site during the convalescent period that a pseudarthrosis would develop, the ends of the bone becoming covered with fibrocartilage and held together by a fibrous capsule. This complication of diaphyseal fractures was well known to the surgeons of the day. The operation was performed on 22 November 1826 before a large group of students and physicians at the Pensylvania Hospital (figure 10.5). The upper end of the femur was divided with a narrow saw, the entire operation requiring only seven minutes. The wound was approximated with adhesive plaster and the limb immobilized in a long leg splint. Starting on the twenty-first postoperative day, the limb was regularly moved through a slowly increasing range of motion. Two months postoperatively the patient was allowed to get up and walk with the aid of crutches. As the patient progressed with weight-bearing and movement it was noted that muscles about the hip, which had been atrophic, gradually increased in size and strength. The success of his operation led Barton to reflect upon the possibility of carrying out similar procedures for ankylosis of other joints, with the following caveat:

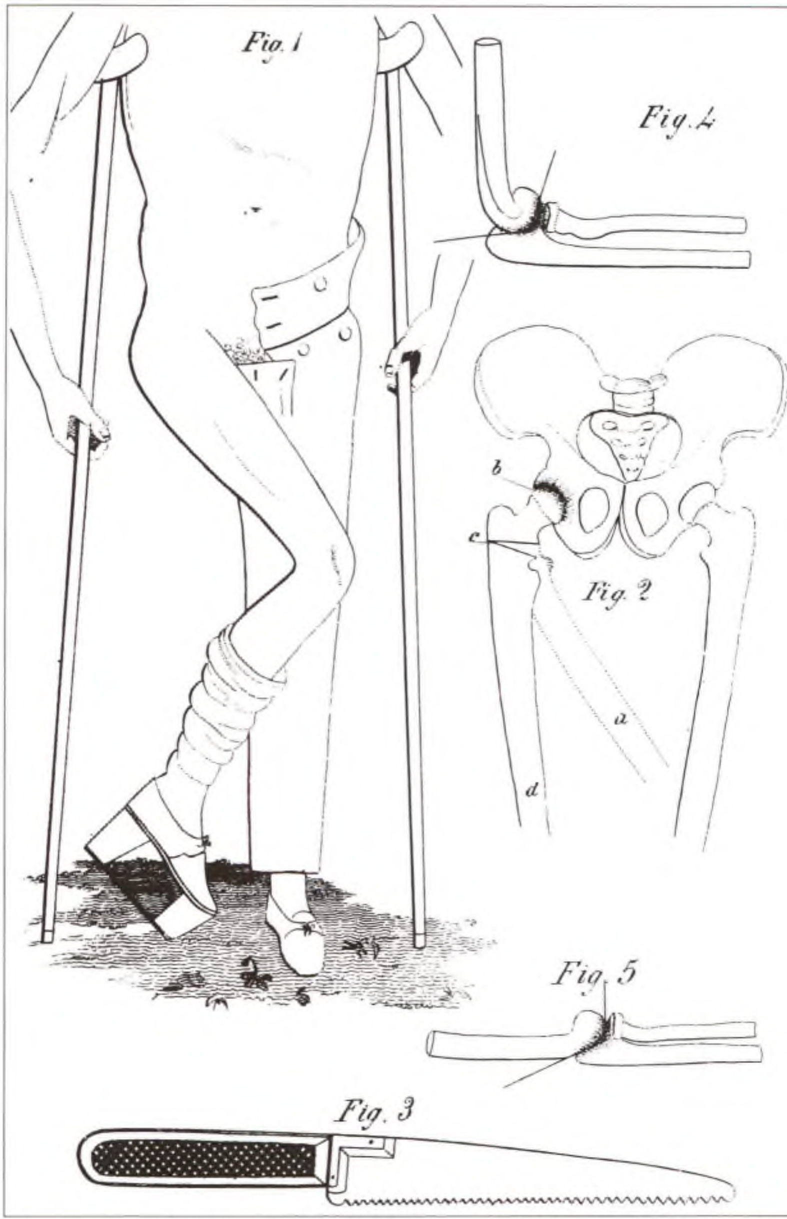

Figure 10.5 Illustration of Barton's patient, the site of the osteotomy, the saw made for Barton, and the possible application of such an operation to an ankylosed elbow. From John Rhea Barton, "On the Treatment of Anchylosis by the Formation of Aritficial Joints," *N Am Med Surg J* 3(1827): 279–92.

I hope I will not be understood as entertaining the belief, that this treatment will be applicable to, and judicious in, every case of anchylosis. I believe the operation would be justifiable only under the following circumstances, viz. Where the patient's general health is good, and his constitution is sufficiently strong; where the rigidity is not confined to the soft parts, but is actually occasioned by a consolidation of the joint; where all the muscles and tendons, that were essential to the ordinary movements of the former joint, are sound, and not incorporated by firm adhesions with the adjacent structure; where the disease causing the deformity, has entirely subsided; where the operation can be performed thrugh the original point of motion,

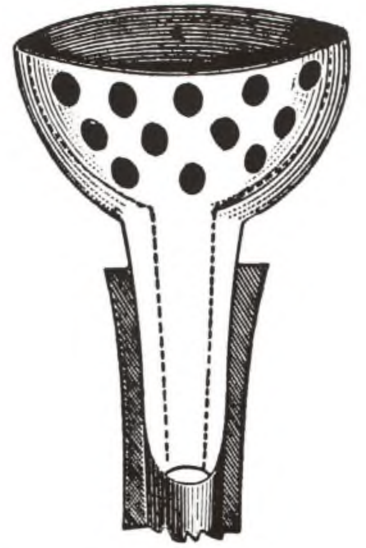

Figure 10.6 The ivory prosthesis designed by Gluck for the upper end of the tibia to be used in arthroplasty of the knee. From Nicolas Senn, *Tuberculosis of the Bones and Joints* (Philadelphia: F. A. Davis Co. Pub., 1901), 463.

or so near to it, that the use of most of the tendons and muscles will not be lost; and, finally, where the deformity, or inconvenience, is such, as will induce the patient to endure the pain, and incur the risks of an operation.[29]

This statement regarding the indications for arthroplasty has retained its validity for over 150 years.

In 1863 Lewis Sayre (1820–1900) reported two cases of ankylosis of the hip treated by procedures similar to Barton's.[30] In one case he was able to retrieve the hip area at autopsy six months after the operation and found that the new joint was surrounded by a capsular ligament lined with a synovial membrane and that the ends of the bones were covered with cartilage. This idea of producing a new joint biologically, by effecting an artful pseudarthrosis, was unique. Barton's work was well known to European surgeons who applied his principle especially to ankylosis of the temperomandibular joint.[31] One of these was Aristide Verneuil (1823–1895), a student of both Jacques Lisfranc and J.-F. Malgaigne, who was the chief surgeon at the Hôpital de la Pitié in Paris. The idea of marshaling the reparative forces of the body to effect the restoration of a joint damaged by infection or injury was explored thoroughly by Louis Ollier (1825–1901) in 1867.[32] Further clinical applications of Ollier's ideas were attempted primarily within the larger arena of reconstructive surgery rather than in the narrow application to arthroplasty. In a paper entitled "Autoplasty – Transplantation – Implantation of Foreign Bodies" published in 1894, Themesticles Gluck (1853–1942) reviewed a vast literature on these subjects, with particular emphasis on the tolerance of the soft tissues to large foreign bodies.[33] He was taken particularly with the use of prostheses made of ivory and described not only intramedullary pegs but also a devise for hemiarthroplasty of the knee (figure 10.6). He also utilized a perforated ivory disc in repairing large inguinal hernias. Gluck was born in Roumania, the son of a physician. He was educated in Leipzig and Berlin, where he was an assistant to both Ernst von Bergmann and Bernhard Langenbeck. After his training was completed he returned to Bucharest as the professor of surgery for a short time before returning to Berlin, where he spent the rest of his career as the chief of a major hospital. He had a broad interest in reconstructive surgery.

In Paris Jules Péan (1830–1898) (figure 10.7) pursued similar ideas. Péan was born and educated in Paris. He became one of the best known surgeons of his era because of his work in abdominal and gynecological surgery. The title of his thesis for the medical degree in 1860, "De la scapulalgie, et de la résection scapulo-huméraire," indicated that he was acquainted with surgery of the extremities. In 1894, in a paper that included a report of two other cases of reconstruction of the orbit and nose

Figure 10.7 A portrait of Jules Emile Péan (1830–1898) in the operating room made by Henri Toulouse-Lautrec. From Tomaso Lugli, "Artificial Shoulder Joint by Péan (1893)," *Clin Orthop* 133(1978): 215–18.

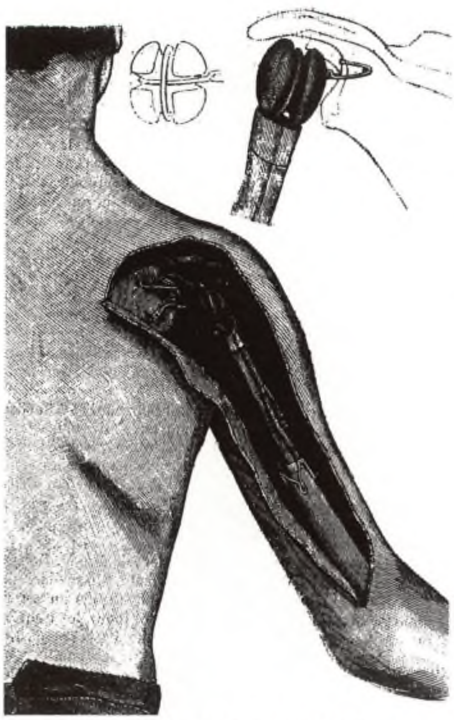

Figure 10.8 Illustration of Péan's patient with the total shoulder joint in place. Note the extent of the upper humerus removed. From J. E. Péan, "Des moyens prothétiques," *Gaz hôp civ milit* 67(1894): 289–92.

with prostheses made of platinum, he described a patient with advanced tuberculosis of the shoulder joint with extension far down into the humerus.[34] After excision of all of the infected bone and soft tissue, the defect in the bone was reconstructed by means of a prosthesis made of hard rubber and platinum prepared by his dentist, J. Porter Michaels[35] (figure 10.8). The initial result of the operation was very satisfactory and the patient regained good function. However, the tuberculosis recurred several years later negating the result. At the end of his article Péan drew the following conclusions:

1) *It is possible to replace an important portion of the skeleton, even an enarthrodial joint.*
2) *To be well tolerated prostheses must not only be sterile but also made of nonresorbable (non-reactive) materials.*
3) *They will be tolerated by the organism provided one carries out the necessary precautions.*
4) *This procedure can replace immediate amputation of a limb when the patient refuses such an operation.*
5) *In the ordinary large excision, this method has the advantage of preventing the immediate collapse of the soft parts.*
6) *Finally, such prostheses can provide a method which permits the preservation of joint motion.*[36]

Péan's interest in prostheses continued and he took advantage of the newly discovered X-rays to design individual prostheses for the femur and tibia.[37] His death in 1898 put an end to these developments.

Péan's conclusions indicated that he was well aware of the goals of the operation called arthroplasty as defined by the MacAuslands.

In general terms, an arthroplasty is the creation of an artificial joint for the purpose of restoring motion to a joint which is either completely ankylosed, or which has such a limited degree of motion that the limb is not serviceable. Under the heading arthroplasty might be grouped all operations regardless of the nature of their technique, which have for an object the increasing of the motion of a joint. In recent years, the term arthroplasty has come to be used in a restricted sense. The procedure is defined as a highly technical one that aims to restore motion by reconstructing the component parts of the joint and by interposing a substance between the articular ends to prevent re-ankylosis, and to act as a substitute for the normal cartilage lining.

An arthroplasty, to measure up to its true standard, not only must increase the arc of motion of a joint, but also must preserve stability. Whereas the value of other mobilizing methods may be estimated according to the mobility obtained by operation, the intrinsic

Figure 10.9 John B. Murphy (1857–1916). From Loyal Davis, *J. B. Murphy: Stormy Petrel of Surgery* (New York: G. P. Putnam's Sons, 1938), frontispiece.

worth of an arthroplasty depends far more upon the retention of stability and firmness than upon the return of motion to the normal arc. A joint is functional only when it is stable. The true test of an arthroplasty lies in positive answers to the following questions: Is there sufficient motion in the joint to increase function? Is the motion painless? Is the joint stable? An arthroplasty that does not measure up to these requirements is not a success.

A sharp distinction may be drawn between an arthroplasty and an excision. The advocates of the resection operation pay no regard to stability. The procedure involves the removal of a sufficient amount of bone to allow free play between the articular surfaces, with the result that the joint is hypermobile in all directions.[38]

Ollier's work provided the stimulus for another approach to arthroplasty, the interposition of autogenous tissue flaps between the joint surfaces. A leading proponent of this approach was the Chicago surgeon, John B. Murphy (1857–1916) (figure 10.9). Murphy was born near Appleton, Wisconsin, of immigrant Irish parents.[39] He was raised on a farm, attended country school, and graduated from high school in Appleton. He began to study medicine as a preceptor of a local physician. When he was twenty-one he went to Chicago to attend Rush Medical College. After graduation he spent some time abroad visiting the famous surgical clinics before starting his own practice in Chicago in 1894. Murphy was a hard-working entrepeneur who popularized the diagnosis and operative treatment of appendicitis and devised the first widely used method of intestinal anastomosis, known as the *Murphy button*. He became a professor of surgery at Rush Medical College and Northwestern Medical College. In 1911 he was elected president of the American Medical Association. Murphy also had an important role in the founding of the American College of Surgeons, one of whose important properties in downtown Chicago is the John B. Murphy Memorial Building.

Murphy based his work on animal experiments and carried out his first arthroplasty in 1902. In an extensive report of his clinical experience, presented before the American Surgical Association in 1913, he cited the results of eighty-four operations, among which were procedures on the hip, knee, toe, elbow, and temperomandibular joint.[40]

The main principle of the operation consists in interposing between the ends of the bones after their separation, some material which will prevent recurrence of bony union. Various substances have been used for this purpose, but we are firmly convinced that the best interposing material is a pedicled flap of fat and fascia lifted from the tissues in the neighborhood of the joint, or if that is not possible, then a detached flap of fat and fascia from the trochanteric portion of the fascia lata may be transplanted between the ends of the bones,

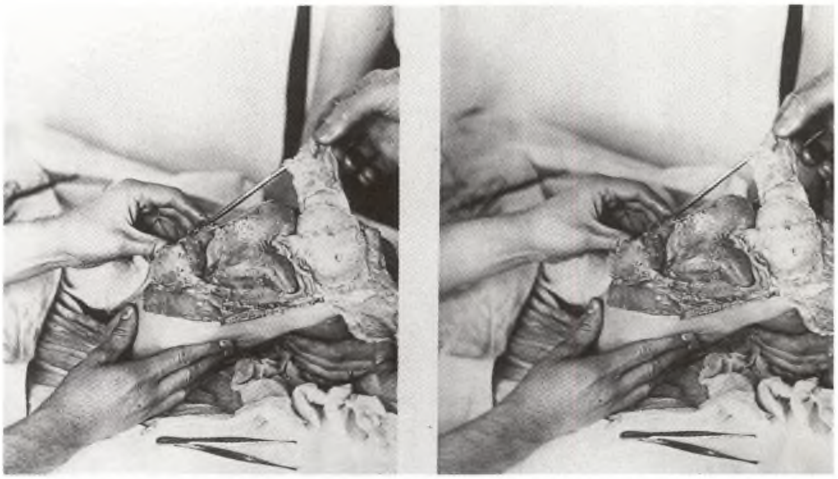

Figure 10.10 One of many sets of stereoscopic photographs of a dissection of the knee demonstrating Murphy's method of arthroplasty. This shows how the lateral tissue flaps were raised before suturing them into place across the joint. From J. B. Murphy, *Stereo-Clinic: Arthroplasty for Ankylosed Knee* (Baltimore: The Southworth Co., Pub., 1910), photo #7.

as we have done in two cases. We have observed these cases for so long a time that we are assured of the correctness of this statement. Homo- and hetero-transplants are not uniform in results[41] [figure 10.10].

Figure 10.11 William Stevenson Baer (1872–1931). From *J Bone Joint Surg* 13(1931): 623.

Among the instruments that Murphy designed for arthroplasty of the hip were the well-known reamers to shape the acetabulum and head of the femur. Murphy was satisfied with his technique and believed that good results could be obtained by other surgeons if his methods were carefully followed.

The American Orthpaedic Association took up the subject of arthroplasty in a symposium held at their meeting in 1917. The principal paper was given by William S. Baer (1872–1931) (figure 10.11) of Johns Hopkins University, and consisted of a well-illustrated report of one hundred patients on whom he had carried out arthroplasty.[42] Rather than using the patients own tissue as an interposing membrane as Murphy had done, Baer utilized sheets of pigs bladder treated with a potassium chromate solution. This material became known as *Baer's membrane*. Like chromic catgut, the similarly treated pigs bladder was gradually absorbed over a period of two or three months. The use of the prepared membrane limited the extent of the dissection required for the operations and made them considerably simpler. Baer was born and educated in Baltimore, where he received both his undergraduate and medical degrees from Johns Hopkins University. In 1900 he was placed in charge of the newly established orthopedic clinic of the university, which under his direction developed into the Department of Orthopedic Surgery. His ability as a teacher was recognized when he was appointed the first professor of orthopedic surgery at Johns Hopkins University. He developed the Children's Hospital School in Baltimore for the care of crippled children.

Figure 10.12 Marius Nygaard Smith-Petersen (1886–1953). From *J Bone Joint Surg* 35A(1953): 104–20.

A new form of interposition arthroplasty of the hip was introduced by Marius Nygaard Smith-Petersen (1886–1953) (figure 10.12) in 1939. Smith-Peterson was born in Grimstad, Norway. He emigrated to the United States at the age of sixteen and attended the universities of Chicago and Wisconsin, receiving his undergraduate degree in 1910. He graduated from Harvard Medical School in 1914. During World War I he served in the First Harvard Medical Unit in France. He studied and worked with Elliott G. Brackett at the Massachusetts General Hospital, where he was appointed chief of orthopedics in 1929. His interest in hip surgery was expressed in his description of a new surgical approach to the hip joint and the design of a three-flanged nail for the internal fixation of intracapsular fractures of the hip, which he inserted through this approach.[43]

Smith-Petersen's development of what became known as the *mould arthroplasty* began with an observation similar to that of Gluck's. In 1923 he noted that a piece of glass that he removed from a patient's back was surrounded by a glistening synovial sac containing a few drops of fluid.

> *This benign reaction to an inert foreign body gave rise to the thought that here was a process of repair which might be applied to arthroplasty. This first thought gradually developed and the idea of the "mould" was conceived. A mould of some inert material, interposed between the newly shaped surfaces of the head of the femur and the acetabulum, would guide nature's repair so that defects would be eliminated. Upon completion of the repair the mould would be removed, leaving smooth, congruous surfaces mechanically suited for function.*[44]

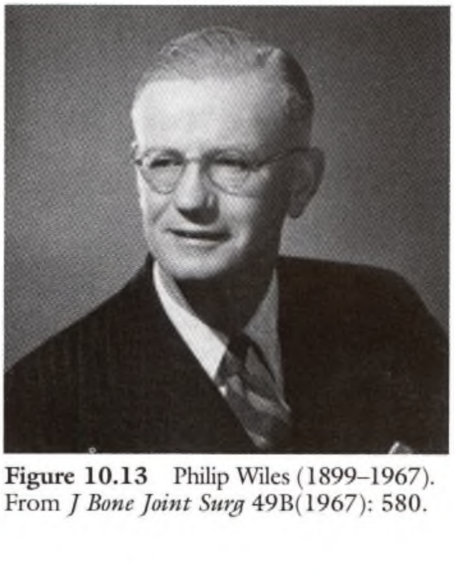

Figure 10.13 Philip Wiles (1899–1967). From *J Bone Joint Surg* 49B(1967): 580.

The original glass moulds or cups were not strong enough and often resulted in late breakage. Cups of various plastic materials were tried, but they too failed and Smith-Petersen returned to glass. Finally in 1937 on the advice of his dentist he tried the nonreactive metal alloy Vitallium, carrying out the first Vitallium mould arthroplasty of the hip in 1938.[45] Smith-Petersen published the preliminary report on his procedure in 1939.[46] For the next thirty years, it was the preferred method of arthroplasty of the hip.[46] However, even though this procedure was preferred, it required a prolonged rehabilitation program to insure the success of the operation. This added to the cost and tried the patience of both surgeon and patient.

The success of the hip prostheses introduced for the treatment of intracapsular fractures of the neck of the femur after World War II was an important stimulus for the further improvement of methods of arthroplasty.[48] Philip Wiles (1899–1967) (figure 10.13) at the Middlesex Hospital in London carried out a hip arthroplasty using an acetabular cup and a femoral hip prosthesis in 1938. Both components were held in place with screws. Wiles's

Figure 10.14 John Charnley (1911–1982). From William Waugh, *John Charnley: The Man and the Hip* (London: Springer-Verlag, 1990), frontispiece.

work on this technique was interrupted by World War II and it was not until 1958 that he reported on his method, which he had used in eight patients.[49] Wiles was born and raised in London, where his father was a privy councillor. He served in the Royal Flying Corps in World War I and in the medical services in World War II. He was an excellent teacher and was greatly admired by his colleagues, but he was a restless spirit and retired early at age sixty without pursuing his initial experiments with total hip replacement.

In 1953 Edward J. Haboush (1904–1973) at the Hospital for Joint Disease in New York published a report of his work with the use of a hip prosthesis and an acetabular cup.[50] After several unsuccessful trials, he finally chose to use an acetabular cup of Vitallium with a matching stemmed hip prosthesis. Both of the components were held in place with dental acrylic. The paper contained the first extensive biomechanical analysis of such a system. Seven years later John Charnley (1911–1982) (figure 10.14) again called attention to the value of methylmethacrylate as a bone cement in fixing femoral-head prostheses to the shaft of the femur.[51]

During the next fifteen years several surgeons utilized metal hip prostheses seated in a metal acetabular cups in carrying out total hip replacement.[52] While many of these procedures were successful, the problem of wear between the metal components made it clear that better wearing surfaces were needed. Charnley was responsible for the next major step forward. Charnley was born into a family of modest circumstances in the industrial town of Bury only a short distance from Manchester.[53] His father ran a small drugstore and did minor dentistry in the rear of his establishment; his mother was a nurse. Charnley was educated in the local schools before moving on to the medical school in Manchester from which he graduated in 1935. After a variety of appointments he returned to the Royal Infirmary in Manchester as a resident casualty officer, where he fell under the influence of Harry Platt, who made Charnley his protégé. World War II intervened and Charnley spent the next six years as a medical officer. For most of this period he was in Cairo, where he had time to develop his mechanical aptitudes. Following his return to Manchester he slowly moved up the ladder of appointments. In 1950 he published a valuable monograph, *The Closed Treatment of Common Fractures*, which was the best exposition of the principles taught by Hugh Owen Thomas and Robert Jones.[54] Three years later this work was followed by *Compression Arthrodesis*, in which he described his instrumentation and methods for performing this procedure.[55] He next turned to the subject of arthroplasty. After a long period of trial and error he came up with his final design, which he called the "low friction arthroplasty."[56]

Figure 10.15 Alfred B. Swanson (b. 1923). Courtesy of Dr. Swanson.

Through dogged persistence and hard work Charnley convinced the Manchester Regional Hospital Board to allow him to develop the Centre for Hip Surgery at Wrightington Hospital in Wigan and to place him in charge. He utilized his position there to continue to improve his methods and as a focus for teaching his methods to surgeons from around the world. It was here that he developed the clean-air enclosure to lower the 7 percent incidence of infection in his operations.[57] A number of designs were used until the principle of laminar air flow enclosures were well established.[58] Other improvements in aseptic technique were introduced along with the enclosures. The success of Charnley's innovations revolutionized arthroplasty, leading to the design and use of total joint replacement in all of the major joints. It also shifted the thrust of orthopedic research from a search for biological solutions for such problems to a search for biomechanical ones.

The restoration of motion and function to hands severely affected with rheumatoid arthritis required a completely different approach. In contrast to the development of total joint replacement, which was the result of a long process involving the contributions of many individuals, the introduction of silicone implants was the result of work of one man, Alfred B. Swanson (b. 1923) (figure 10.15) of Grand Rapids, Michigan. The use of this material was based on his observations of silicone implants inserted to cushion the end of long bones following amputations, as well as extensive animal experiments. His clinical results were impressive.[59] These implants have made the the treatment of hand disabilities much more effective and have done for the small joints of the hand and foot what total joint replacement has done for the rehabilitation of the large joints such as the hip and knee. Swanson was educated at the University of Illinois and had broad postgraduate training at various midwestern universities. His practice as a hand surgeon gave him access to a large number of patients with hands crippled with arthritis and injuries. His work with these patients led to a very substantial improvement in the care of such patients throughout the world.

A common precursor of osteoarthritis of the knee has been injury of the *meniscii*, or semilunar cartilages of the knee. William Bromfeild (1713–1792), a London surgeon and a contemporary of John Hunter, made the following observation in 1773:

I have seen a temporary lameness happen, from one of the semilunar cartilages within the joint of the knee, having flipped out of its situation; the knee immediately became swelled, and very painful. This case I first discovered by accident for the assistant having hold of the leg, and sometimes lightly extending, at other times gently bending it, while I was examining the joint of the knee the cartilage slipped into its place and the patient soon became easy.[60]

William Hey (1736–1819), a student of Bromfeild, who coined the term *internal derangement*, gave this description of his mode of treating this disorder:

> *To remedy this derangement, I placed my patient upon an elevated seat, which had nothing underneath it that could prevent the leg from being pushed backward towards the posterior part of the thigh. I then extended the joint by the assistance of one hand placed just above the knee, while with the other hand I grasped the leg. During the continuance of the extension I suddenly moved the leg backwards, that it might make an as acute an angle with* [the] *thigh as possible. This operation I repeated once, and then desired the young lady to try how she could walk. Whatever may be thought of my theory, my practice proved successful; for she was immediately able to walk without lameness, and on the third day after this reduction she danced at a private ball without inconvenience, or receiving any injury from the exercise.*[61]

The gross pathology of a torn meniscus was described by the Edinburgh surgeon, John Reid (1808–1848) in 1834.

> *The fibrous tissue connecting the outer margin of the external semilunar cartilage to the edge of the head of the tibia was torn through in its anterior half, and the semilunar cartilage was found thrown inwards and backwards, and placed between the spine of the tibia, the posterior crucial ligament, and posterior ligament of Winslow. The transverse ligament was entire. The cartilage itself was considerably flattened and broader, and the remaining portion of the fibrous tissue, connecting its outer margin to the tibia, was much thickened, and had assumed somewhat of a fibrocartilagenous appearance. The cartilage of the anterior part of the tibia which had been exposed to the free motion of the condyle of the femur had become rough.*[62]

It is interesting that in this early description there was already a comment about damage to the articular cartilage, a condition that is a precursor of osteoarthritis. The differential diagnosis between loose bodies and tears of the meniscii was established by B. E. Brodhurst (1822–1900) by 1867.[63]

Amédée Bonnet (1809–1858) carried out extensive experiments upon fresh cadavers in order to reproduce the mechanism of meniscal injuries.[64] Bonnet compared the effects of forced extension, forced flexion, varus and valgus stress, and rotation of the knee in aged and debilitated patients, healthy patients, and children. The manipulations in the aged and debilitated subjects resulted in fractures; in the healthy younger subjects, avulsions of the ligaments; and in children, epiphyseal injuries. In one experiment, the body of a healthy young adult was placed face down, the knee was flexed to a right angle and the tibia was externally ro-

Figure 10.16 Thomas Annandale (1838–1907). From *Quasi Cursores: Portraits of High Officers and Professors of the University of Edinburgh at It's Tercentenary Festival*, drawn and etched by William Hale. (Edinburgh: Edinburgh University Press, 1884).

tated. A snap was heard, and when the knee was dissected, the medial meniscus was found to be torn. Further experiments showed that tears of the meniscus could be easily produced in this manner. Bonnet showed that the displaced meniscus could be reduced by manipulation of the knee first into full flexion and then into full extension.

During the first two-thirds of the nineteenth century, internal derangements of the knee, or meniscal injuries, were treated by manipulation because of the danger of infection posed by open operations. Many bone-setters were very good at treating such injuries. The procedure used by one of the Sweet family of bone-setters, well known throughout New England, was described this way:

Figure 10.17 Eugen Bircher (1882–1956). From *Schweiz med Wschr* 72 (1942): 177.

Kneeling down before the patient, he took the foot with the hollow of his hand beneath it, and twisted it so as to turn the toes somewhat outward. He then pressed the part just above the injured knee with his other hand, and with a sudden, quick moving of the foot in a proper direction brought the heel into contact with the lower part of the body. This motion he repeated three times in succession. Then rising from the floor, he bade him walk. Hazard to his great surprise, was able to rise and walk about the room as well as ever, except for the feeling of great weakness in the joint.[65]

The introduction of antiseptic surgical technique by Lister in 1865 allowed arthrotomies to be carried out with a greatly reduced risk of infection. In 1879 Thomas Annandale (1838–1908) (figure 10.16) of Edinburgh began to carry out menisectomies.[66] Annandale was born and educated in Newcastle-on-Tyne before attending the University of Edinburgh.[67] He was one of James Syme's house officers and continued on the staff of the Edinburgh Royal Infirmary. In this position he had a good opportunity to observe Lister work out the details of his antiseptic techniques. When Lister moved to London in 1877, Annandale succeeded him in the chair of clinical surgery. In 1883 he gave the following account of a meniscectomy on a thirty-year-old miner:

An incision was made along the upper and inner border of the tibia, parallel with the anterior margin of the internal semilunar cartilage; and the few superficial vessels having been secured, the joint was opened. It was then seen that this semilunar cartilage was completely separated from its anterior attachments, and was displaced backwards about half an inch. The anterior edge of this cartilage was now seized by a pair of artery catch forceps, and it was drawn forwards into its natural position, and held there until three stitches of chromic catgut were passed through it and through the fascia and periosteum covering the margin of the tibia. The forceps were then withdrawn, the cartilage remaining securely stitched in position. The wound in the synovial membrane and soft textures having been closed with catgut stitches, a splint and plaster of Paris bandage were applied, so as to keep the joint at rest.[68]

Arthrotomy of the knee for the treatment of tears of the meniscii quickly became a common operation.[69] Until the introduction of arthroscopy and arthroscopic surgery, the basic techniques of menisectomy remained unchanged.

The development of arthroscopy was a slow process, beginning in 1879 when Max Nitze (1848–1906) devised an electrically lighted cystoscope and demonstrated that it was possible to carry out operations through the instrument.[70] In 1910 Hans Christian Jacobaeus (1879–1937) adapted the cystoscope for the examination of the pleural and peritoneal cavities.[71] Eleven years later, Eugen Bircher (1882–1956) (figure 10.17) used a modified Jaco-

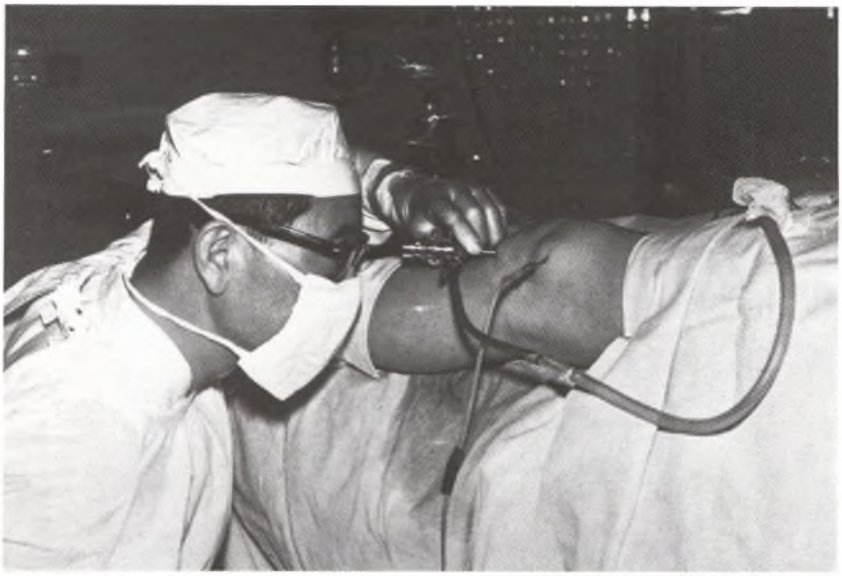

Figure 10.18 Masaki Watanabe using the No. 21 arthroscope. From a brochure published by Kamiya Tsusan Kaisha Ltd., n.d.

baeus laparoscope to visualize the interior of the knee in eighteen patients.[72] He published a more complete report the following year.[73] He found that the pathological changes that he visualized through the arthroscope did not correlate very well with the X-ray findings. In nine patients in whom a diagnosis of a torn menicus was made with the arthroscope, tears were found in eight at arthrotomy.

Bircher was the director of the Kanton Hospital in Aarau, Switzerland, where he was well known for his work on gunshot wounds, goiter, and gastric surgery.[74] In addition to being a senior officer in the Swiss army, he was active in politics. He also was editor of the *Schweizerischen medizinische Wochenschrift* for many years. Bircher never followed up on his initial work with the arthroscope, presumably because of the press of other activities.

Phillip Kreuscher (1885–1943) of Chicago designed an arthroscope and reported his experience with its use in 1931. The title of his article, "Semilunar Cartilage Disease: A Plea for Early Recognition by Means of the Arthroscope and the Early Treatment of this Condition," indicates that he was enthusiastic about the possibilities of this diagnostic method, but he failed to pursue his studies further.[75] Micheal Burman (1896–1974), while working as a resident in Christian George Schmorl's (1861–1932) clinic in Dresden, carried out extensive studies in fresh cadavers using an arthroscope to visualize not only the knee joint, but also the shoulder, elbow, wrist, hip, and ankle joints. The results of this work were reported in 1931.[76] On his return to the Hospital for Joint Diseases in New York City, he was able to convince two of his colleagues to try the method clinically.[77] This trial failed to create any interest in the method.

Figure 10.19 Robert W. Jackson (b. 1932). Courtesy of Dr. Jackson.

Kenji Takagi (1888–1963) of Japan began his attempt to design a suitable arthroscope as early as 1918.[78] He persevered through a long series of modifications, each one slightly better than the last. In spite of the difficulties with the instruments he remained convinced that the method would become important. Takagi was fortunate because he had a student who followed up on his work and made the breakthrough that propelled the methodology to the forefront during the last quarter of the twentieth century. Masaki Watanabe (b. 1911) (figure 10.18) was trained by Takagi in the Department of Orthopaedic Surgery at Tokyo University and imbued with his professor's interest in the technique. After his military service in World War II, Watanabe transferred to the Tokyo Teishin (Postal Services Ministry) Hospital where he slowly modified, designed, and redesigned instruments for arthroscopy. In this work he was greatly aided by the director of the hospital, Akira Takahashi, who was a pioneer in the use of cystoscopy in Japan. With the introduction of the No. 21 arthroscope, the technique came of age. In 1957 Watanabe and his colleagues published an atlas of arthroscopy and began slowly to introduce intra-articular operative techniques carried out under the vision provided by the arthroscope, that is, arthroscopic surgery.[79] This activity was little noted outside of Japan.

In 1964 Robert W. Jackson (b. 1932) (figure 10.19) went to Japan on a fellowship to study tissue culture techniques, and while he was there he took the opportunity to become acquainted with Watanabe's team and to observe their operations.[80] On his return to the Toronto General Hospital, he obtained a No. 21 arthroscope and began using it. It was largely due to the early efforts of Jackson that arthroscopy and arthroscopic surgery were introduced to the orthopedic surgeons of the English-speaking world. Jackson was born, raised, and educated in Toronto. His postgraduate training included stops at the Massachusetts General Hospital and the Royal National Orthopaedic Hospital. From early in his career he was identified as the possessor of an inquiring mind and the qualities that make a superior teacher. His participation in sports as a young man gave him a continuing interest in athletes and their injuries. He moved up the academic ladder, becoming a professor of orthopedic surgery at the University of Toronto in 1982. He remained in this position until 1991 when he moved to Dallas to head the orthopedic department at the Baylor University Medical Center. In the United States, Richard L. O'Connor (1933–1980) made substantial contributions to arthroscopic surgery by the development of instruments and techniques for intra-articular operations under arthroscopic control. He was responsible for the training of many of his colleagues in the methods of arthroscopic surgery.[81] The major development that has led to the widespread use of arthroscopic surgery, as well as all endoscopic operations, was the introduction of fiberoptics and their marriage to minature television cameras. This technique was introduced in 1972 by Watanabe.[82]

Joint replacement and arthroscopic surgery were the two most important innovations in orthopedic surgery during the last half of the twentieth century. Both of these were made possible by new developments in technology. The design and manufacture of the components for total joint replacement utilized many methods used in the aerospace industry. This was the case particularly when the metal titanium was used. Endoscopy, and arthroscopy especially, gained widespread acceptance only after the introduction of fiberoptic materials and the design of the small television cameras that have displaced the optical systems.

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CHAPTER ELEVEN

Tumors of Bone and Soft Tissues

ANECDOTAL REPORTS OF tumors of bone and soft tissue are not uncommon in the older literature[1] (figure 11.1). In 1803 William Hey (1736–1819) published an account of ten patients with tumors, five of which may have been soft tissue sarcomas of the neck or extremities. On the basis of their gross appearance, they were called *Fungus haematodes*, from the Latin term for fungus[2] (figure 11.2). John Abernethy (1764–1831) introduced the term *sarcoma* from the Greek, meaning a fleshy excrecence.[3] Although the *Oxford English Dictionary* attributes the word to Galen, it is interesting that Galen in his work on the classification of tumors, *De tumoribus praeter naturam*, written at the end of the second century A.D., did not employ the term.[4] In a paper first published in 1804 and later incorporated in his collected works under the title "An Attempt to Form a Classification of Tumors According to Their Anatomical Structure," Abernethy begins:

> *In attempting a classification of tumours, I shall suppose that they may be made to constitute an Order in the class of local diseases in nosology; and the meaning of the word may be restricted in the manner suggested, to substances of new formation, which made no part in the original stucture of the body; the order may then be divided into genera; and the first genus may be denominated from its most obvious character, (that of having a firm and fleshy feel,) Sarcoma, or Sarcomatous tumours.*[5]

The species in this genera were: (1) the common vascular or organized sarcoma, (2) the adipose sarcoma, (3) the pancreatic sarcoma, (4) the cystic sarcoma, (5) the tuberculated sarcoma, (6) the pulpy or medullary sarcoma, and (7) the carcinomatous sarcoma. This classification was based entirely on the gross char-

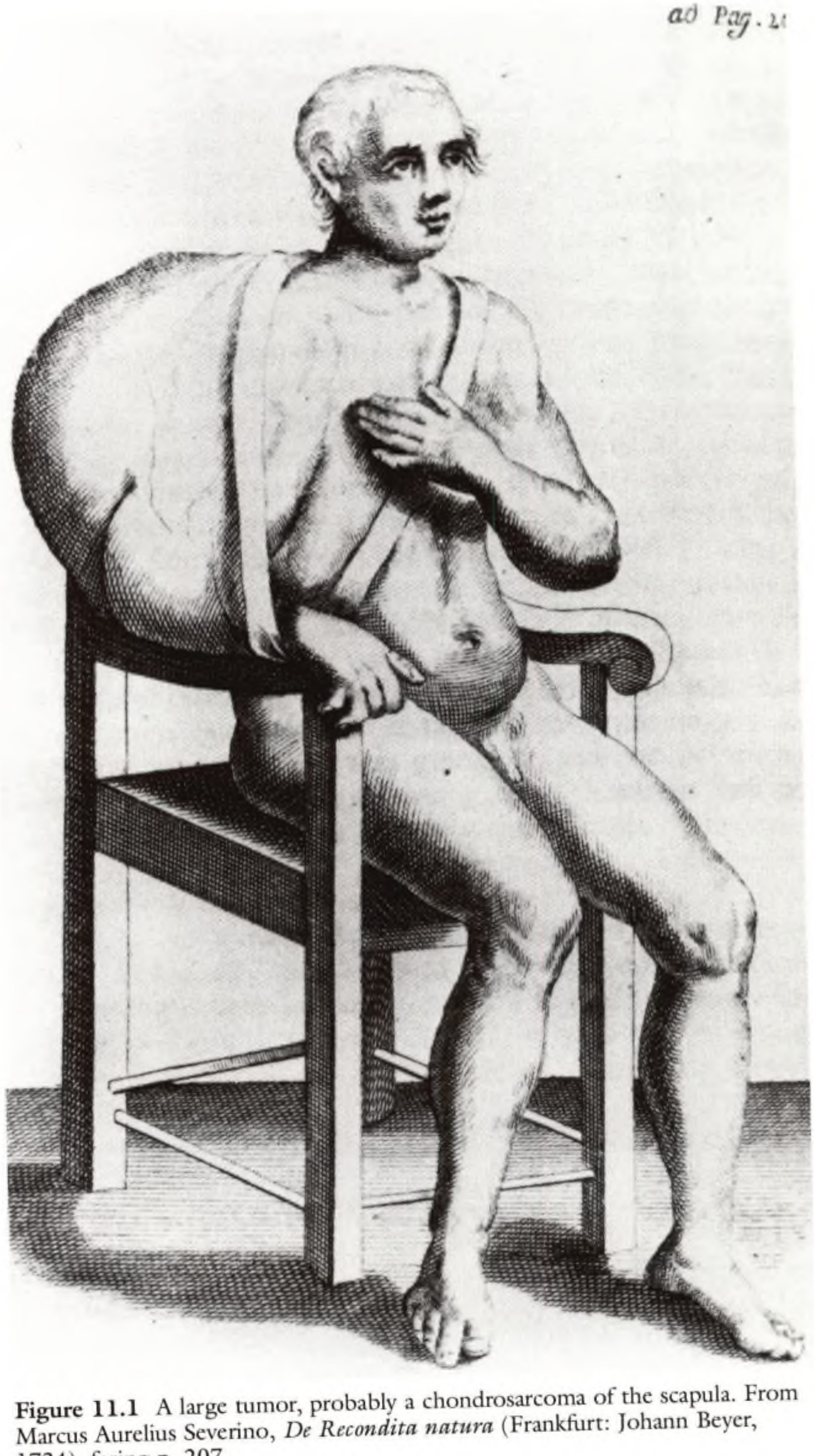


Figure 11.1 A large tumor, probably a chondrosarcoma of the scapula. From Marcus Aurelius Severino, *De Recondita natura* (Frankfurt: Johann Beyer, 1724), facing p. 207.

Figure 11.2 An example of *fungus haematodes.* From William Hey, *Practical Observations in Surgery*, 2d ed. (London: T. Cadell & W. Davies, 1810), pl. 10.

acteristics of the specimans and clinical examples of each type were presented. A forty-five-year-old woman with a large tumor of the tibia was used to typify the first species, a man with an adipose tumor of the thigh, the second. The clear separation of cancerous tumors from the others is significant. Alexis Boyer (1757–1833) introduced the term *osteosarcoma* when he differentiated this tumor from exostosis, gumma of bone, and *spina ventosa*[6] (figure 11.3).

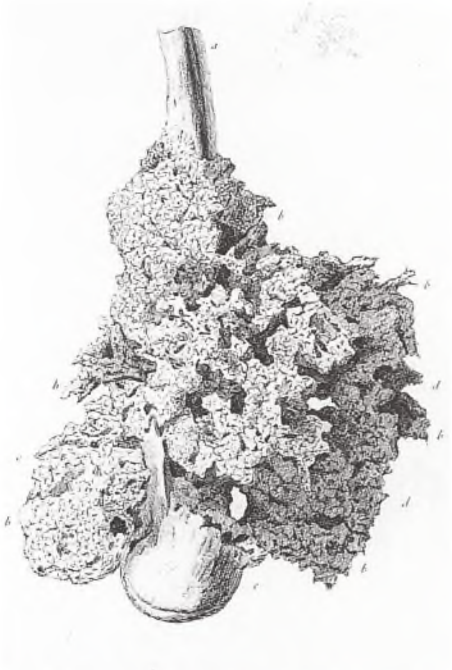


Figure 11.3 A specimen of an osteosarcoma. From Alexis Boyer, *Traité des maladies chirurgicales et des opérations qui leur conviennent* (Paris: V. Migneret, 1814), vol. 3, pl. 6.

A contemporary of Abernethy's, Astley Patton Cooper (1768–1841), in a paper published in 1818, presented a classification of bone tumors, again based upon the gross characteristics of the lesions.[7] Under the term *exostosis* Cooper discriminated between periosteal and medullary tumors of either a cartilagenous or fungous nature (figures 11.4–11.5). The course of a substantial number of cases, most of which were malignant tumors, was presented. In his description of a distant spread of a fungous exostosis of the medullary membrane, Cooper explained that

> *it often happens in this disease, that tumors of a similar kind form in other parts of the body during its progress; so also when the affected limb has been amputated, a similar disease will occur at a future period, and in organs of the greatest importance to life.*[8]

Ligation of the arterial supply to some tumors was carried out without effect. Amputation was held out as the only hope for cure.

In discussing the differential diagnosis of osteosarcoma, *spina ventosa*, and tubercles in bone, Guillaume Dupuytren (1777–1835) commented that

> *osteo-sarcoma, which is a true cancerous degeneration of bone, manifests itself in the form of a white or reddish mass, lardaceous and firm at an early stage of the disease; but presenting at a later period, points of softening, cerebriform matter, extravasated blood,*

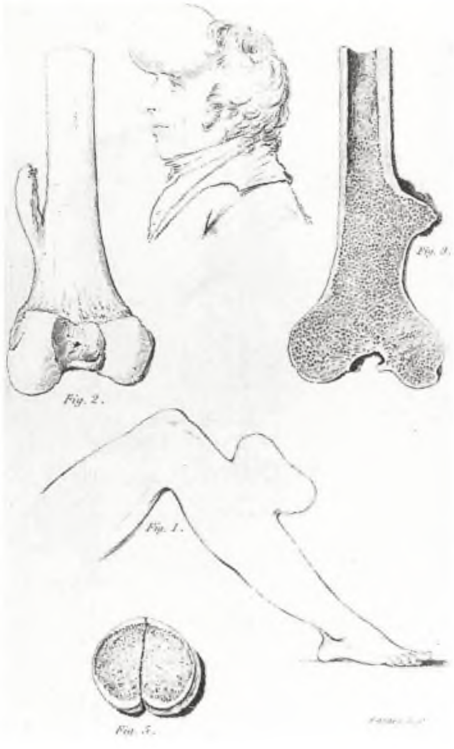
and white or straw-coloured fluid of a viscid consistence in its interior. These characters distinguish osteo-sarcoma from spina ventosa [tuberculous dactylitis], *the two agreeing in exhibiting increased dimensions in the affected part; but this condition is dependent, in the latter, on swelling of the bone itself, attended by thinning and separation of its laminated texture. Towards their close these diseases present other points of resemblance; thus, it is not uncommon to find spina ventosa passing into a cancerous state, or to see osteo-sarcoma accompanied by partial vascular or fleshy productions. In general, however, the one belongs rather to the class of fungous diseases, and the other to cancer.*

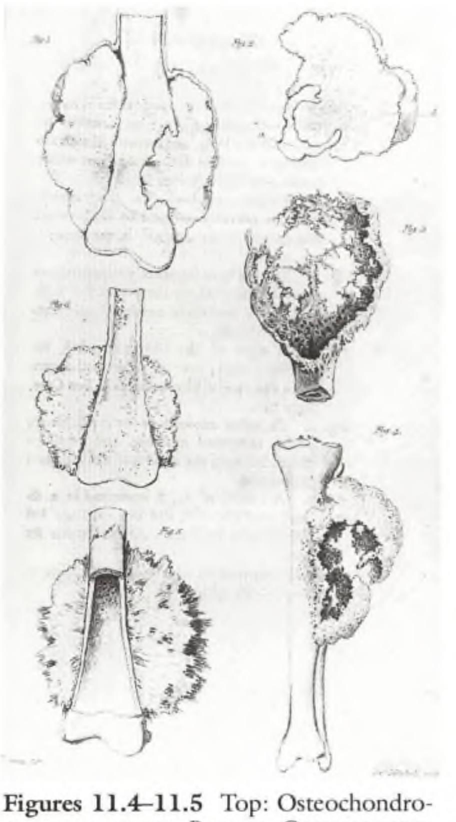
Osteo-sarcoma attacks more particularly the jaws and the extremities of the long bones. It is also frequently observed on the iliac bones and in the neighborhood of the acetabulum.[9]

The study of the spread of cancer by Joseph Claude Recamier (1774–1852), who introduced the term *metastasis*, helped to explain the difference between those tumors arising primarily in bone and soft tissues, and those that involved the bone secondarily (sarcomas vs. metastatic carcinomas).[10] The gross pathology of all of these tumors was presented in an outstanding manner by one of Dupuytren's students, Jean Cruveilhier (1791–1873), in his magnificant two-volume work on pathological anatomy replete with colored ilustrations, published between 1829 and 1842.[11]

The next stage in our understanding of bone and soft tissue tumors was provided by the work of Hermann Lebert (1813–1878) (figure 11.6), who first described the microscopic anatomy of bone tumors in 1845[12] (figure 11.7). Lebert studied in Berlin and Zurich, where he obtained his medical degree in 1834.[13] He practiced in Paris and was made professor of clinical medicine in Zurich and later in Breslau at the Friedrich-Wilhelm Universität. From this point on, as a result of both Rudolf Virchow's and Lebert's work, all papers dealing with bone and soft tissue tumors would be accompanied by descriptions of the cellular structure of the tumors. Examples of this are the first monograph on tumors of synovial tissues, written by Louis-Marie Michon (1802–1866) and the first monograph devoted to giant-cell tumors of bone by Eugène Nélaton, a nephew of the famous surgeon Auguste Nélaton[14] (figure 11.8).

In his three-volume work on tumors published in 1863/67, Rudolf Virchow (1821–1902) described six different types of sarcomas: fibrosarcoma, myxosarcoma, gliosarcoma, melanosarcoma, chondrosarcoma, and osteosarcoma.[15] The first complete classification of tumors derived from mesoblastic tissues, which includes sarcoma, was proposed by E. Ziegler in 1885.[16] Advances in the classification and the understanding of sarcomas of bone and soft tissue did little to ameliorate the desperate situation of patients





Figures 11.4–11.5 Top: Osteochondromas or exostoses. Bottom: Osteosarcomas. From *Astley Cooper and Benjamin Travers, Part I*, 3d ed. (London: Cox & Son, 1818,), pls. 8–9.

Figure 11.7 An example of some illustrations of cartilagenous tumors showing the histology. From Hermann Lebert, *Physiologie pathologique des recherches cliniques, experimentales, et microscopiques, etc.* (Paris: J. B. Baillière, 1845), atlas pl. 17.

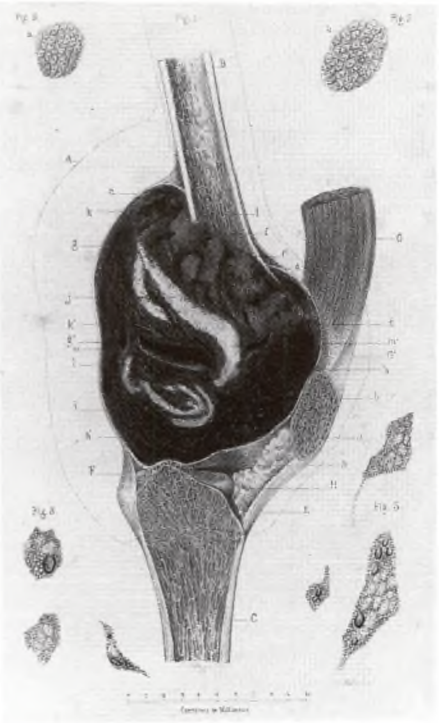


Figure 11.8 A plate showing the gross and microscopic appearance of a giant-cell tumor. From Eugène Nélaton, *Mémoire sur une nouvelle espèce de tumeurs bénignes des os, ou tumeurs à myeloplaxes* (Paris: Rignoux 1860), pl. 3.

Figure 11.6 Hermann Lebert (1813–1878). Courtesy of the National Library of Medicine, Bethesda, MD.

with such tumors (figures 11.9–11.10). Before the advent of anesthesia and the introduction of antiseptic-aseptic surgical techniques, resorting to excision or amputation was delayed until the case was far advanced, and even then these methods promised only palliation, not a cure.

Samuel Weissel Gross (1837–1889) (figure 11.11) was the son of Samuel D. Gross, one of the greatest American surgeons of the nineteenth century, and is frequently confused with his father.[17] After graduating from Jefferson Medical College in 1857, he began his practice in Philadelphia. This was interrupted by extended service in the Union army during the Civil War. In 1876 he was married to Grace Linzee Revere, who was seventeen years younger than he. He succeeded his father as professor of surgery at Jefferson Medical College in Philadelphia in 1884. Widely respected as a teacher and surgeon, his death of an acute infection in 1889 at the age of fifty-two shocked the community. His widow remarried one of his colleagues in 1892 and became Lady Osler. In 1879 Gross published a paper entitled "Sarcoma of the Long Bones, Based on a Study of One Hundred and Sixty-Five Cases."[18] He discussed the histology, general pathology, symptomatology, diagnosis, prognosis, and treatment, and included a comprehensive review of the world literature upon the subject.

Figure 11.9 A tumor of the humerus in a sixteen-year-old woman four years after onset. From William Gibson, *The Institutes and Practice of Surgery* (Philadelphia: Carey & Lea, 1832), vol. 1, facing p. 248.

Figure 11.10 A tumor of the femur in a nine-year-old boy. From Gibson, *Institutes and Practice of Surgery*, vol. 1, facing p. 246.

Figure 11.11 Samuel W. Gross (1837–1889). From Mark Ravitch, *A Century of Surgery.* Portrait courtesy of the College of Physicians of Philadelphia.

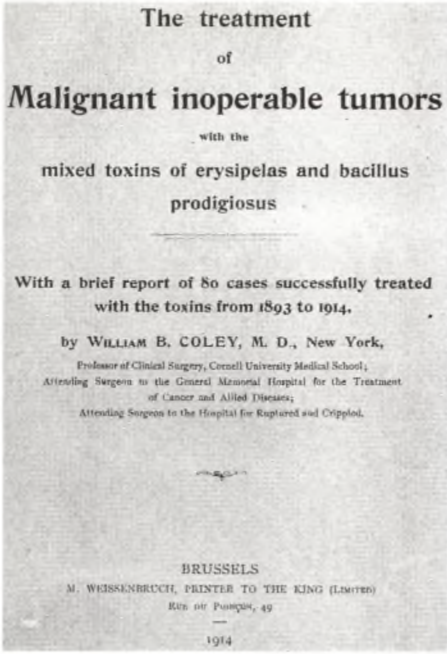
Figure 11.12 William B. Coley (1862–1936). From *Trans Am Surg Assoc* 54(1936): 415.

I have limited my investigations, however, to those cases alone in which the histological features of each form of sarcoma were typical, and I have used none, except for a few of osteoid sarcoma, about the true nature of which there could be no doubt, that were not confirmed by microscopical examination.[19]

Of the 165 tumors, 70 were giant-cell sarcomas, 45 periosteal osteoid sarcomas, 16 central spindle-celled sarcomas, 13 periosteal round-celled sarcomas, 12 central round-celled sarcomas, and 9 periosteal spindle-celled sarcomas. He gave a good description of their gross and microscopic features. He noted that the lymphatics were rarely involved; that spread was usually to the lungs, viscera, and other bones; that the histology of the metastases was similar to that of the primary tumor; and that there were discrete areas of spread of the tumor in the bone marrow above the primary lesion that influenced the level of amputation. He observed that giant-cell sarcomas tended to recur after local excision but that only 22 percent were malignant. He believed that some of these tumors could be treated by local excision. It is interesting, that while he advocated amputation as the best treatment for most of the sarcomas of bone, the mortality rate related to the operation itself at that time was 31 percent. This paper has a very modern ring and was the best work of this type published in the nineteenth century.

Because of delays in diagnosis, amputations were almost always done to control the local growth of the tumor, in other words, for palliation. The operations were associated with a significant morbidity and mortality and the long-term survival rates were very low. For this reason, alternative methods of treatment appeared to be attractive. William B. Coley (1862–1936) (figure 11.12) encountered a patient on the surgical service of the New York Hospital whose clinical course surprised him.

My attention was first called to the curative effect of accidental erysipelas in inoperable sarcoma by a certain case observed in 1891. In my studies of sarcoma at that time I made a careful analysis of all the cases of sarcoma (90 in number) operated upon at the New York Hospital during the preceding fifteen years. Among these cases was one of a small round-cell sarcoma of the neck, four times recurrent. At the fifth operation, in 1884, Dr. Bull found the tumour to involve the deep structures so extensively that it was impossible to remove it, and he gave up the attempt. The case was regarded as absolutely hopeless, when shortly after the operation, the man developed a very severe attack of accidental erysipelas in the face and neck, followed two weeks later by a second attack. Within a few days after the beginning of the first attack the tumor began to soften and decrease rapidly in size. The history stated that when the patient left the hospital his tumours had entirely disappeared. There was no after-



The treatment

of

Malignant inoperable tumors

with the

mixed toxins of erysipelas and bacillus prodigiosus

With a brief report of 80 cases successfully treated with the toxins from 1893 to 1914.

by WILLIAM B. COLEY, M. D., New York,

Professor of Clinical Surgery, Cornell University Medical School;
Attending Surgeon to the General Memorial Hospital for the Treatment of Cancer and Allied Diseases;
Attending Surgeon to the Hospital for Ruptured and Crippled.

BRUSSELS

M. WEISSENBRUCH, PRINTER TO THE KING (LIMITED)

Rue du Poinçon, 49

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1914

Figure 11.13 The title page of Coley's book on the use of his toxins.

Figure 11.14 Ernest A. Codman (1869–1940). From *Trans Am Surg Assoc* 59 (1941): 612.

record of the case, but I made an effort to trace the patient, and finally found him alive and well, with no evidence of any local or generalized recurrence in the spring of 1891, seven years later. He was examined by Dr. Bull and myself.[20]

Based on a review of the literature and this experience, Coley began to inoculate patients with inoperable tumors with cultures of streptococci from cases of erysipelas and later with sterilized suspensions of such cultures. The results were encouraging.[21] He later added sterilized cultures of *Bacillus prodigiosus* to the suspension of sterilized streptococci. The resulting mixture became known as *Coley's toxins.* The long-term results of use of this method in ninety cases, many of them bone tumors, was reported in 1914[22] (figure 11.13). Coley was the founder of immunotherapy and, because his toxins were used not only in inoperable lesions but also following definitive operations for malignant bone tumors, he was also the founder of adjuvant therapy.

Coley was a graduate of Yale College and Harvard Medical School.[23] He was associated with New York Hospital and with the New York Cancer Hospital (later to be called the Memorial Hospital for the Treatment of Cancer and Allied Diseases and now the Memorial-Sloan-Kettering Cancer Center), where he did most of his work on malignant disease. In 1902 one of his patients established the Collis P. Huntington Fund for Cancer Research, the first cancer research fund in the United States. After a distinguished career as a surgeon in New York City, Coley retired in 1932. Coley's toxins disappeared from the therapeutic armamentarium after World War II, to be replaced shortly thereafter by the use of a growing variety of chemotherapeutic drugs used individually or in combination.[24] His son Bradley L. Coley (1892–1961) succeeded his father as head of the bone tumor service at the Memorial Hospital and published a book on bone tumors and related conditions, which went through two editions.[25]

With the exception of exostoses, most of the benign tumors with which we are familiar were not discussed, or indeed not even known, until the turn of the twentieth century. The discovery of X-rays in 1896 changed this dramatically, introducing new methods of both diagnosis and treatment. Ernest A. Codman (1869–1940) (figure 11.14) was a pioneer in the study of bone tumors using this new medium.[26] He was Boston born and bred, attended Harvard College and Harvard Medical School, eventually ending up at the Massachusetts General Hospital. In his autobiographical preface to his book on the shoulder, he gives a good account of his early work with X-rays.[27] His observations were not appreciated by his colleagues and were published finally as a chapter in a surgical encyclopedia. In this chapter he gives his description of what has become known as *Codman's triangle*: an X-ray finding suggestive of malignancy.

In many cases near the junction of the healthy bone with the tumor, there is a reactive new bone formation beneath the periosteum. At the edge of the tumor this layer of new bone ends abruptly and gives a charcteristic appearance in the skiagraph.[28]

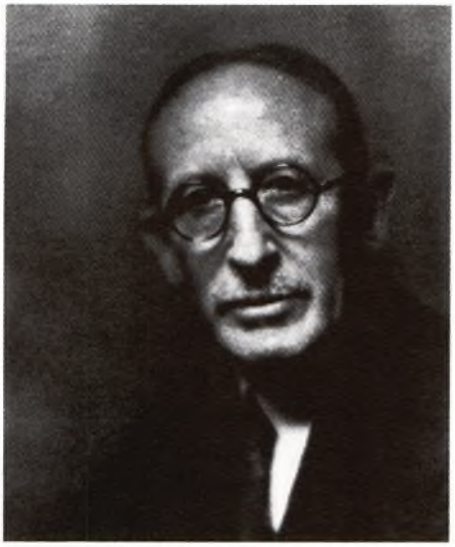


Figure 11.15 James Ewing (1866–1943). From *Arch Path* 36(1943): 326.)

His study of X-rays of the shoulder led to the definition of the tumor *chondrobastoma*, or *Codman's tumor.*[29] Codman was a founder of the American College of Surgeons. Working through this organization, he did much to disseminate the growing body of information regarding the diagnosis and treatment of bone tumors.

The use of X-ray techniques to study malignant bone tumors was particularly valuable because it led to earlier diagnosis and the possibility of initiating treatment before the tumors metastasized. In addition, the widespread use of X-rays revealed a number of benign bone tumors whose presence and character had never been suspected before. As experience with X-rays increased, they became increasingly important in the differential diagnosis of bone tumors. The development of computerized tomography (CT) in the 1970s and magnetic resonance imaging (MRI) in the 1980s added further noninvasive tools to the diagnostic armamentarium.

The therapeutic applications of the X-rays were exploited along with their diagnostic applications.[30] X-rays and radium were quickly applied to the treatment of malignant bone tumors. The early results were not promising. In 1905 Coley concluded that

in view of this practically constant tendency to early recurrence, furthermore, in the absence of any reported cases well beyond 3 years, the method should never be used, except in inoperable cases or as a prophylactic after operation, as a possible, though not yet proven, means of avoiding recurrence.[31]

James Ewing (1866–1943) (figure 11.15) was a great advocate of the use of radiation therapy using either X-rays or radium.[32] Ewing graduated from the New York College of Physicians and Surgeons in 1891 and eight years later, after studying abroad and deciding on a career as a pathologist, became the first professor of pathology at Cornell University.[33] He had a pivotal role in the development of the Memorial Hospital for Cancer and Allied Diseases, first as director of research and later as director of the entire hospital. His textbook of pathology, published in 1919, was highly regarded.[34] He described the bone tumor that bears his eponym, *Ewing's sarcoma*, in 1921.[35] He was a founder of the American Cancer Society and his contribution to public education regarding cancer was recognized by an article that appeared in the 12 January 1931 issue of *Time.*[36] Ewing's bias against the operative treatment of bone tumors even extended to biopsy, which he believed to be unneccessary in most cases. Writing in 1922 he stated:

Figure 11.16 The result of placing the cut section of the humerus directly on a photographic plate for five days, indicating the amount of radioactive material in the tissue of this patient. From Harrison S. Martland and Robert E. Humphries, "Osteogenic Sarcoma in Dial Painters Using Luminous Paint," *Arch Path* 7(1929): 413.

I believe that with present resources, the suspicion of bone sarcoma should not be taken as a sign for operation. The diagnosis in the great majority of cases can be accomplished on clinical history, roentgen-ray findings, and the results of therapeutic tests with roentgen ray or radium. The therapeutic test is at the same time the best treatment for a large portion of bone sarcomas. In short the non-operative treatment of these diseases is the goal to be aimed at.[37]

In 1926 he reported three patients who had malignant bone tumors that were treated by radiation, followed by recurrence and amputation.[38] In each case there was evidence of radiation osteitis.

Evidence was accumulating that in addition to osteitis, radiation could produce malignant changes in the bone. Harrison Stanford Martland (1883–1954), a pathologist in Newark, New Jersey, reported the tragic deaths of young women employed to paint watch dials with luminous paint contaning crystalline phosphorescent zinc sulfate, radium, mesothorium, and radiothorium. While the majority died of aplastic anemia, some died of osteogenic sarcoma[39] (figure 11.16). His reports were followed quickly by that of Hermann Kuttner describing the development of malignant bone tumors in association with the radiation treatment of bone and joint tuberculosis.[40] Giant-cell tumors of bone were commonly treated with X-ray radiation and good results were reported.[41] Enthusiasm for this method of treatment waned with the first report of sarcomas originating in previously benign giant-cell tumors exposed to irradiation treatment, which were followed shortly by other reports confirming the first.[42] Irradiation therapy became reserved for those lesions considered to be inoperable because of location.

The treatment of osteogenic sarcoma in the United States in the 1940s and 1950s was greatly influenced by two papers from a radiologist, Albert B. Ferguson (1895–1976) from the New York Orthopaedic Dispensary and Hospital, that espoused conservative management. Because these were published in the most influencial orthopedic journal of the day, they had a wide impact upon orthopedic practice.

The treatment recommended for osteogenic sarcoma of an extremity is: 1. Avoidance of early amputation; 2. Delay of amputation; 3. Radiation before amputation; 4. Radiation, excision, and implantation of a bone graft or bone chips before amputation, with amputation following before recurrence becomes evident; 5. Repetition of excision before amputation, if recurrence is evident before amputation has been done.[43]

The optimum time for amputation is a quiet period in the course of the disease, — a period when the patient is not losing weight; when the phosphatase content of the blood is not elevated; when there has been no sudden or marked increase of pain or swelling for two months; and when there has been no recent marked increase of mass or destruction demonstrated roentgenographically. Such periods occur with some frequencey after the first six months of osteogenic sarcoma, and earlier in the course of the disease may be produced with the potent aid of radiation.

Whatever one may select as the treatment of choice, it can be definitely stated that very early amputation in osteogenic sarcoma of an extremity does not appear to be the best treatment.[44]

Ferguson's views were strongly supported by the distinguished British radiologist J. F. Brailsford (1888–1961).[45] Brailsford even opposed biopsy of the bony lesions and listed the risks.

1. *The risk of the anesthetic.*
2. *The risks of cutting into the lesion.*
   a) Dispersing the infective or malignant cells.

   b) Destruction of the scaffolding on which future reconstructive stability may depend.

   c) Altering the sequence of clinical, histological and radiographic changes by adding the unknown effects of trauma which may further contribute to the difficulty of interpretation of the unusual case.
3. *The dangers of erroneous interpretation; many of which have been illustrated which may:*

a) Lead to the mutilation of a patient with a lesion which would have resolved had efficient treatment been applied.

b) Result in many months delay in securing accuracy of diagnosis.[46]

Stanford Cade (1895–1973), an important British radiation oncologist, supported the views of both Ferguson and Brailsford.[47] If indeed the incidence of metastases was increased by carrying out an open biopsy, and there was never any convincing evidence to support this view, this risk could be reduced to a minimum by the use of aspiration or needle biopsy, as practiced and advocated by Carlos E. Ottolenghi (1904–1984) of Buenos Aires.[48]

Figure 11.17 Joseph C. Bloodgood (1867–1935). From *SGO* 68(1939): facing p. 1965.

The conservative approaches of Ferguson and Brailsford appealed strongly to orthopedic surgeons, who as a group were attracted to the specialty because of a desire to help crippled and handicapped children and who could not bring themselves to perform disabling operations on children who appeared healthy and normal. Most experienced orthopedic surgeons of the period had a defeatist approach to the treatment of malignant bone tumors in children and many of them had not seen a five-year survivor. Brailsford reinforced this attitude by quoting John Hunter: "To amputate is to mutilate a patient you cannot cure."[49] This defeatist attitude helps to explain the skepticism that met the reports, published between 1950 and 1967, of 20 to 25 percent five-year survivals following early amputation as soon as the diagnosis was established.[50] No improvement in these long-term survival rates was seen until after the introduction of cancer chemotherapy used as an adjuvant to surgical treatment.[51]

With surgeons, radiologists, and pathologists all dealing with patients who had bone and soft tissue tumors, good communication was essential and, without a standard nomenclature, impossible. For example, here is the terminology used by eight pathologists to describe the same osteogenic sarcoma: periosteal myxo-sarcoma, myxo-chondro-sarcoma, osteogenic-fibro-myxo-sarcoma, osteo-chondro-sarcoma, mixed cell sarcoma, myxo-sarcoma, fibro-chondro-osteo-psuedo-textoma, and osteo- fibro-myxo-sarcoma.[52] In an effort to correct this situation, the Regents of the American College of Surgeons, under the leadership of Codman, established a Bone Sarcoma Registry in 1921. The three members of the committee were Codman (chairman), Ewing, and Joseph C. Bloodgood (1867–1935) (figure 11.17). Bloodgood, the third member of the triumvirate, was every bit as qualified as his two colleagues. He was a surgeon whose career was spent at the Johns Hopkins Medical School and Hospital.[53] A student of William S. Halsted (1852–1922), Bloodgood was particularly interested in surgical pathology. On the basis of clinical and pathological studies begun in 1892, he reached the following conclusions regarding giant-cell sarcoma:

The ultimate results of the cases of periosteal and medullary giant-cell sarcoma which I have observed personally, and similar records from the literature which I have been able to collect up to the present writing, confirm the conclusion reached many years ago — that conservative treatment is justifiable for this disease. . . . From this investigation it is my opinion that it might be well to drop the term "giant-cell sarcoma", as it gives the wrong impression of the malignancy of the lesion, and use, at least temporarily, the designation "giant-cell tumor".[54]

This was the beginning of an important effort to educate pathologists and surgeons regarding the nature of this tumor and led to a much more conservative approach to management. The term *benign giant-cell tumor* was also used to emphasize this point, but after it had been made, because of the small but real incidence of malignant tumors in this group, the *benign* was dropped.

The Bone Tumor Registry solicited cases from surgeons throughout the country and the procedures for evaluation of the cases were described by Codman.[55] In 1925 Codman published a small volume interpreting the nomenclature used by the committee.[56] In 1927 a more extensive report based on seven hundred cases in the registry was published by Anatole Kolodny (b. 1892) from the Department of Orthopedics of the University of Iowa.[57] The work of the Bone Tumor Registry continued during the next decade, and after a hiatus due to World War II, the collection was refurbished and presented to the Armed Forces Institute of Pathology in 1953.

In 1931, under the aegis of the American Cancer Society, Charles F. Geschickter (1901–1989) from Johns Hopkins University and Murray M. Copeland (1902–1982) from the Memorial Hospital for the Treatment of Cancer and Allied Diseases published a large monograph on bone tumors dedicated to Bloodgood and based on material collected by him at the Johns Hopkins Hospital.[58] A portion of this work was done while the authors were fellows of the Mayo Foundation at the Mayo Clinic. Louis Lichtenstein (1906–1977) and Henry L. Jaffe (1896–1979) who had worked together as colleagues in New York, both published monographs on bone tumors.[59] The bone tumor material from the Mayo Clinic was brought up to date in 1957 by David C. Dahlin (b. 1917).[60] The pathology of the soft tissue tumors was organized by Arthur Purdy Stout (1885–1969).[61] While this work by these pathologists was very important because it affected diagnosis and treatment, it was far from complete. Fully 10 percent of the bone tumors and one third of the soft tissue sarcomas could not be classified accurately.

The giant-cell tumors of bone provided surgeons with a good model on which to develop methods of surgical treatment. The tumors were slow growing and occurred in surgically accessible areas of the metaphyses, usually in adults. They tended to recur

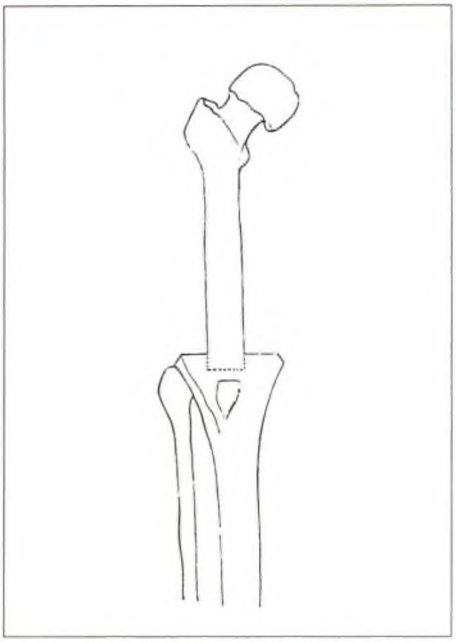
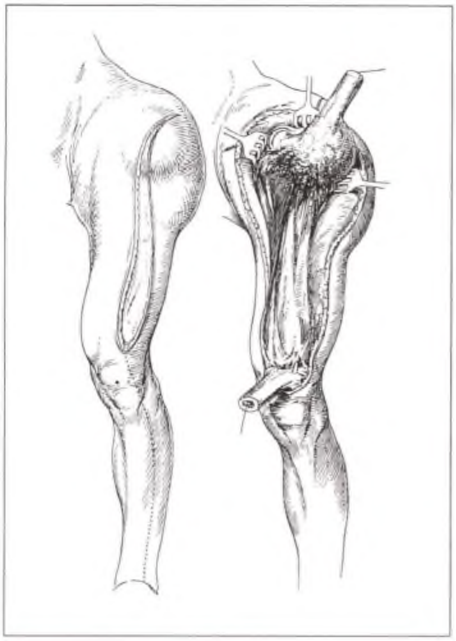
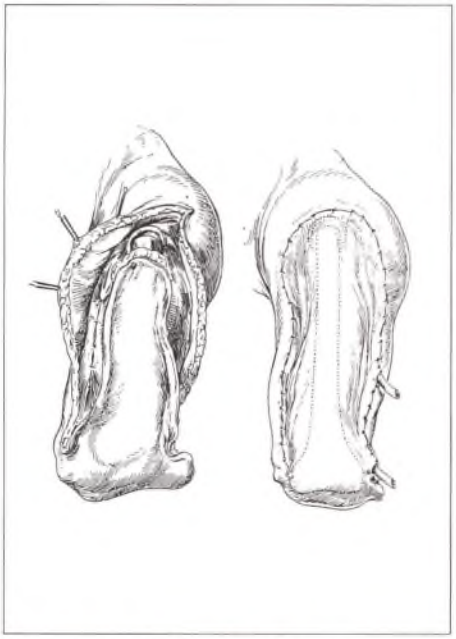


Figure 11.18 A fusion of the femur to the tibia following local resection of a tumor of the distal femur. From Johann Mikulicz, "Über ausgedehnte Resectionen der langen Rohrenknochen wegen maligner Geschwulste," *Arch klin Chir* 50(1895): 666.

locally and metastasized rarely. In 1889 Fedor Krause (1857–1937) in Volkmann's Clinic in Halle reported two cases of what appear to have been giant-cell tumors of the proximal tibia treated successfully by currettage followed by packing with iodoform gauze.[62] The cavities were allowed to heal by granulation. Frank Hinds described a similar case treated by currettage followed by cauterization with zinc chloride and packing with cyanide gauze in 1898.[63] The first operation was followed six weeks later by a second currettage. This case is of interest because it was accompanied by an X-ray of the lesion in the distal femur, and because there was a report seventeen years later that the patient was still working as a wheelwright without any history of recurrence.[64] Bloodgood, in a comprehensive report on the treatment of giant-cell tumors, described treating one of the proximal tibia in 1902 by currettage followed by cauterization of the cavity with phenol.[65] Bloodgood later advocated currettage, followed by cauterization with phenol and alcohol, and then filling the cavity with autogenous bone chips with primary closure of the wound.[66] Cauterization of the lining of the cavity following currettage with liquid nitrogen was introduced in 1965 at the Memorial Hosipital for Cancer and Allied Diseases and was in vogue for a time in spite of the technical difficulties involved in its use.[67] In addition to autogenous and autologous bone grafts, a variety of other materials such as plaster of paris were used to fill the cavities in bone.[68]

While the local excision of what appear to have been exostoses was practiced prior to the introduction of anesthesia and antiseptic-aseptic surgical technique, it was not until the fourth quarter of the nineteenth century that formal local excision of central bone tumors was attempted. These operations were carried out in an effort to preserve some useful limb function. In 1876 in the Middlesex Hospital in London, H. Morris carried out a resection of the distal two-thirds of the radius and two or three inches of the distal ulna for a giant-cell tumor in a thirty-three-year-old woman.[69] Johann Mikulicz (1850–1905) reviewed cases of local resection of bone tumors and reported six patients of his own: two involving the distal radius, one the distal ulna, one the proximal tibia, and two the distal femur.[70] With excision of the distal femur or proximal tibia, a fusion between the femur and tibia was obtained and the leg-length discrepancy managed with an external appliance (figure 11.18). In the patient with resection of the proximal tibia, the fibula was used to aid in the fusion. The use of autogenous bone grafts in the reconstruction of defects produced by the excision of tumors was championed by Fred H. Albee (1876–1945) of New York, who reported a series of thirteen cases in 1936.[71] Resection with reconstruction utilizing large autologous or homologous bone grafts and arthrodesis to preserve limb length have been very successful.[72]





Figures 11.19–11.20 The turn-up plasty of Sauerbruch in which, following resection of the femur, the tibia is turned up to form a proximal stump for the prosthesis. From Ferdinand Sauerbruch, "Die Extirpation des Femur mit Umkipp-Plastik des Unterschenkels," *Dtsch Zeit Chir* 169(1922): 9, 10.

More extensive local excisions were possible. A radical local excision of a tumor of the scapula was carried out by Bernhard Langenbeck (1810–1887) in 1850, but the patient did not survive.[73] A successful operation of this type was carried out in the Surgical Clinic of the University of Tomsk in 1908 by P. I. Tikhov (1865–1917) and the technique was well described by B. E. Linberg (b. 1885) in 1928.[74] The Tikhov-Linberg operation remains an alternative to interscapulothoracic amputation in some cases and permits the preservation of a functional arm and hand.[75] In 1922 Ferdinand Sauerbruch (1875–1951) described an *Umkipp plastic* or *turn-up plasty* procedure in which the femur was excised and the tibia turned up into the defect[76] (figures 11.19–11.20). This allowed for the use of a much more satisfactory prosthesis than if a hip disarticulation had been carried out. This procedure is still used occasionally and William F. Enneking (b. 1926) (figure 11.21) believes it to be the best method of choice for salvaging a failed total femoral device.[77]

A strong voice for limb-preserving methods in the treatment of bone tumors was that of Dallas B. Phemister (1882–1951)[78] (figure 11.22). A graduate of the University of Chicago and the Rush Medical College, Phemister studied abroad in Paris, Vienna, Berlin, and London. In 1926 he was appointed the first professor of surgery in the newly formed medical school of the University of Chicago, a post he held for twenty-six years. Although he was a practicing general surgeon (president of the American College of Surgeons in 1948–49), he had a strong interest in the physiology and pathology of bone. He made substantial contributions to the study of aseptic necrosis of bone, the fate of bone grafts, and the treatment of bone tumors. His work on epiphysiodesis is discussed in chapter 7 of this book. The group of orthopedists who worked in his department, Cly Howard Hatcher (1900–1982), Micheal Bonfiglio (b. 1917), Crawford J. Campbell (1913–1983), Enneking, and Mary S. Sherman (1913–1964), built on this legacy and had influential roles in the education of orthopedic surgeons in bone pathology. Of these people, Enneking has had the greatest influence because of the consistency of his productivity and the outstanding quality of his work, as exemplified in his two-volume handbook entitled *Musculoskeletal Tumor Surgery*.[79]

The treatment of bone tumors by excision and replacement with massive autogenous bone grafts became well recognized as a alternative to amputation. Its success has improved with better methods of graft preservation and improved techniques of internal fixation.[80] Because of the limitation of the supply of autogenous bone graft material from the patient, autologous bone was employed to supplement or substitute for the autogenous grafts[81] (figures 11.23 – 11.25).

Figure 11.21. William F. Enneking (b. 1926). Courtesy of Dr. Enneking.

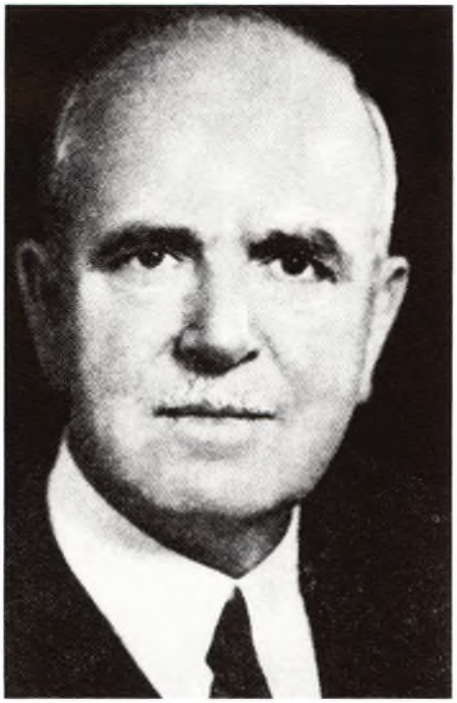
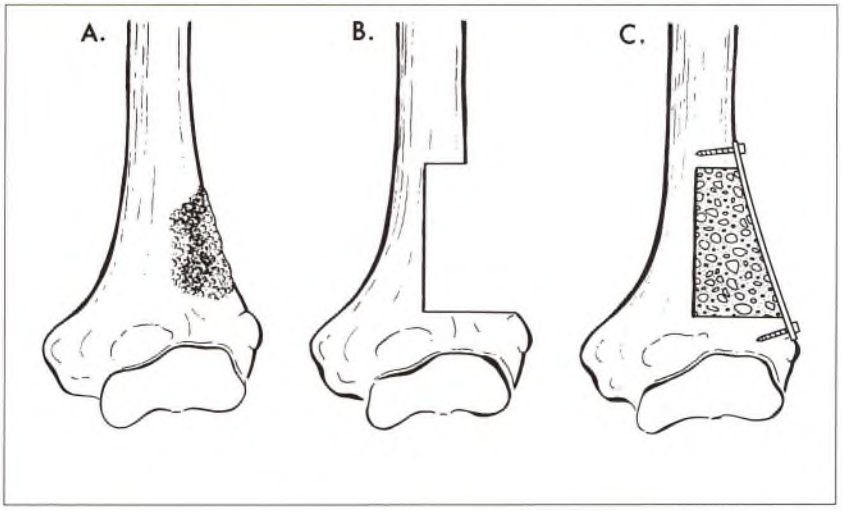
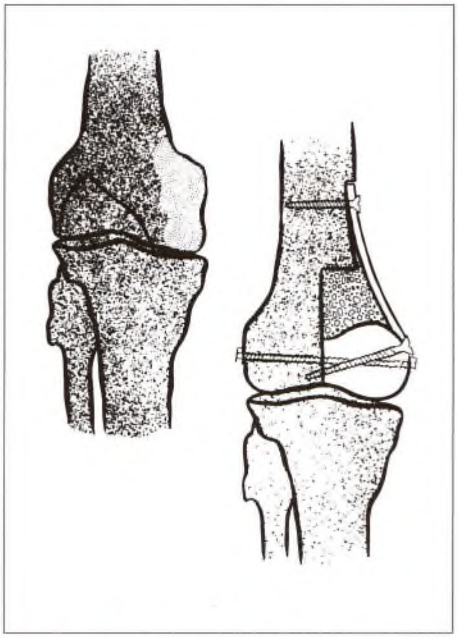


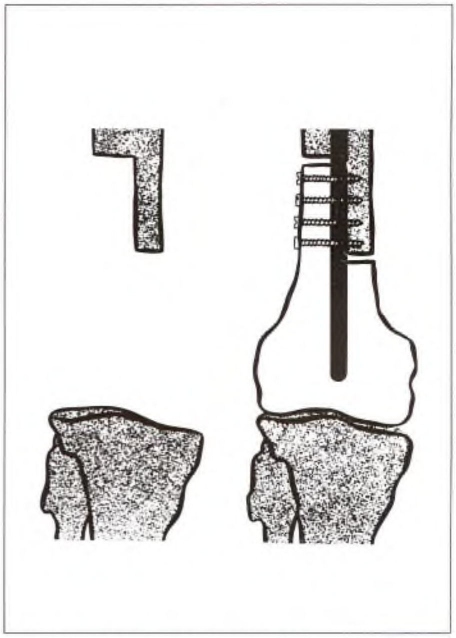
Figure 11.22. Dallas B. Phemister (1882–1951). From Edgar M. Bick, "Phemister of Chicago (1882–1951)," *Clin Orthop* 10(1957): 2.

In 1910 Bloodgood had successfully preserved the function of the knee joint following radical excision of the upper end of the tibia for giant-cell tumor by utilizing the articular surface of the patella supported by a sliding bone graft from the distal tibia[82] (figures 11.26 – 11.27). The patient was able to walk without an external support. The preservation of joint motion by the transplantation of whole autologous joints from cadavers to reconstruct defects produced by the radical local resection of tumors was accomplished by Erich Lexer (1867–1937) (figure 11.28) as early as 1907.[83] After obtaining his medical degree from the University of Würzburg, Lexer worked in the surgical clinic of Ernst von Bergmann in Berlin for a period of twelve years. Proceeding through a series of professorial positions, he finally settled in Munich, where his productivity in the area of reconstructive and plastic surgery was enormous.[84] Lexer demonstrated the value of large autologous grafts and was responsible for encouraging their use. His goal was to develop a method of arthroplasty, rather than the reconstruction of bone defects left after tumor resection. The use of such massive autologous grafts to reconstruct defects produced by the radical resection of bone tumors has been advanced by the work of M. V. Volkov in Russia, Ulf Nilsonne in Sweden, E. V. S. Koskinen in Finland, Carlos Ottolenghi in Argentina, and Henry Mankin in the United States.[85] The behavior of the components of these large autogenous grafts has been thoroughly studied.[86] The work of Louis Ollier (1825–1901) and William Macewen (1848–1924) established the basis of our knowledge of the behavior of bone grafts.[87] Ernest W. Hey Groves (1872–1944) concluded on the basis of experimental and clinical work that "1. Living grafts are better than dead. 2. Autogenous grafts are better than homogenous. 3. Homogenous grafts are better than heterogenous."[88] The great exponent of bone graft surgery in the United States, Fred H. Albee, was preserving bone grafts in 1917 by immersion in vasoline or by wrapping in vasoline gauze and refrigerating at temperatures of four or five degrees Centigrade for up to forty-eight hours.[89] The major stimulus for the development of bone banking did not come until after World War II. In 1947 Leonard F. Bush (1909–1977) from the New York Orthopaedic Hospital published a preliminary report on a bone bank utilizing either refrigeration or freezing of bone grafts.[90] The development of the U.S. Navy Tissue Bank at Bethesda, Maryland, by Georg W. Hyatt (b. 1920) popularized the use of freeze-dried autogenous bone grafts.[91] There has been a continuous improvement in the storage of large autogenous bone grafts.[92]

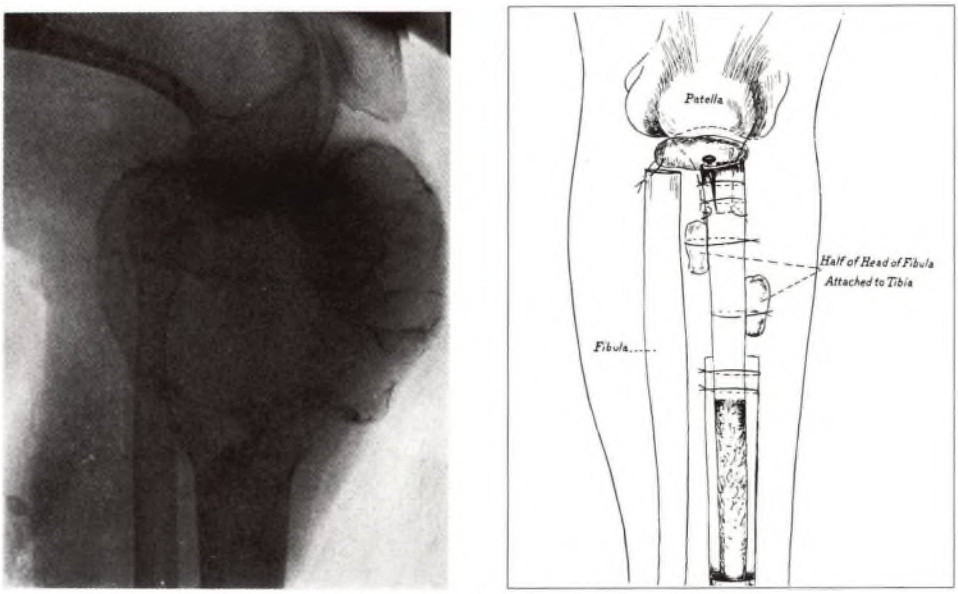
The value of preserving the circulation to a piece of bone transplanted from its bed as a graft was recognized very early. In 1887 Anton von Eiselsberg (1860–1939), a student of Billroth







Figures 11.23–11.25. Methods of reconstructing defects resulting from the local excision of bone tumors using a combination of autogenous and autologous bone grafts. From Frank F. Parrish, "Treatment of Bone Tumors by Total Excision and Replacement with Massive Autologous and Homologous Grafts," *J Bone Joint Surg* 48A(1966): 976, 980, 982.



Figures 11.26–11.27. The reconstruction of the knee joint utilizing the articular surface of the patella and a sliding tibial bone graft, following excision of the proximal tibia for giant-cell tumor. From Joseph C. Bloodgood, "The Conservative Treatment of Giant-Cell Sarcoma, with the Study of Bone Transplantation," *Ann Surg* 56(1912): 228.

Figure 11.28 Erich Lexer (1867–1937). From Hans May, "Erich Lexer: A Biographical Sketch," *Plast Recon Surg* 29(1962): facing p. 141.

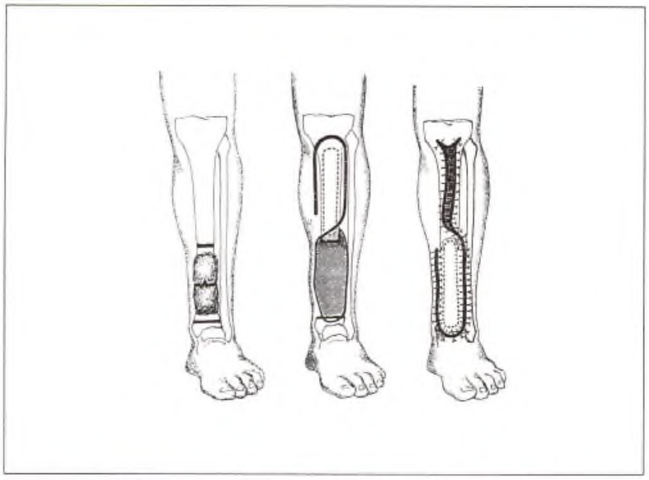


Figure 11.29 A pedicled bone graft. From Anton von Eiselsberg, "Zur Heilung grosserer Defecte der Tibia durch geteilte Haut-Periost-Knochenlappen," *Arch klin Chir* 55(1887): 438.

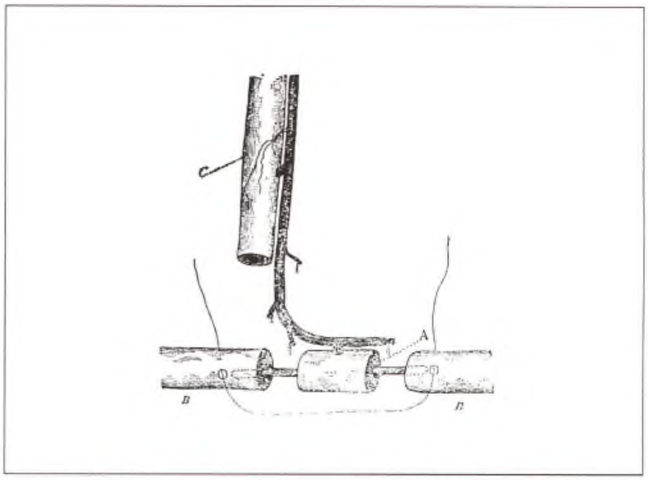


Figure 11.30 A vascularized graft from the ulna of a dog implanted in a defect of the tibia in a boy. From A. M. Phelps, "Transplantation of Tissue from Lower Animals to Man," *Med Record* 39(1891): 224.

and later the chief of the First Surgical Clinic of the University of Vienna from 1901 to 1938, described a method of incorporating a bone graft in a pedicled graft[93] (figure 11.29). One of the earliest bone grafts utilizing a vascular pedicle was a heterograft from a dog. This operation was attempted twice by A. M. Phelps (1851–1902) of New York and reported in 1891.[94] The second patient was a young boy with a congenital pseudoarthrosis of the tibia who had been treated unsuccessfully with an autogenous bone graft. The area of the pseudoarthrosis was excised and a pedicled vascular graft from the proximal ulna of a dog was fixed in place in the defect by means of an intramedullary rod (figure 11.30). The boy and the dog were immobilized in plaster of paris dressings and remained united for six days, at which time the pedicle was divided because of inability to maintain immobilization of the parties. In neither case was the operation a success. The use of free vascularized autogenous bone grafts did not become a real possibility until after the development of techniques for vascular anastomosis by Alexis Carrel (1873–1944), for which he received the Nobel Prize in 1912.[95] The realization of this concept was delayed seventy years and required the development of fine suture materials and techniques of optical magnification that could be used in the operating room.[96]

In 1943 Austin T. Moore (1889–1963) and Harold R. Bohlman (1893–1979) reported the local excision of a large giant-cell tumor of the upper end of the femur with reconstruction of the defect by means of a metallic prosthesis[97] (figure 11.31). Subsequent to this, there has been a large experience with the use of custom-made metal or composite prostheses for the reconstruction of bone defects remaining after the local excision of bone tumors.

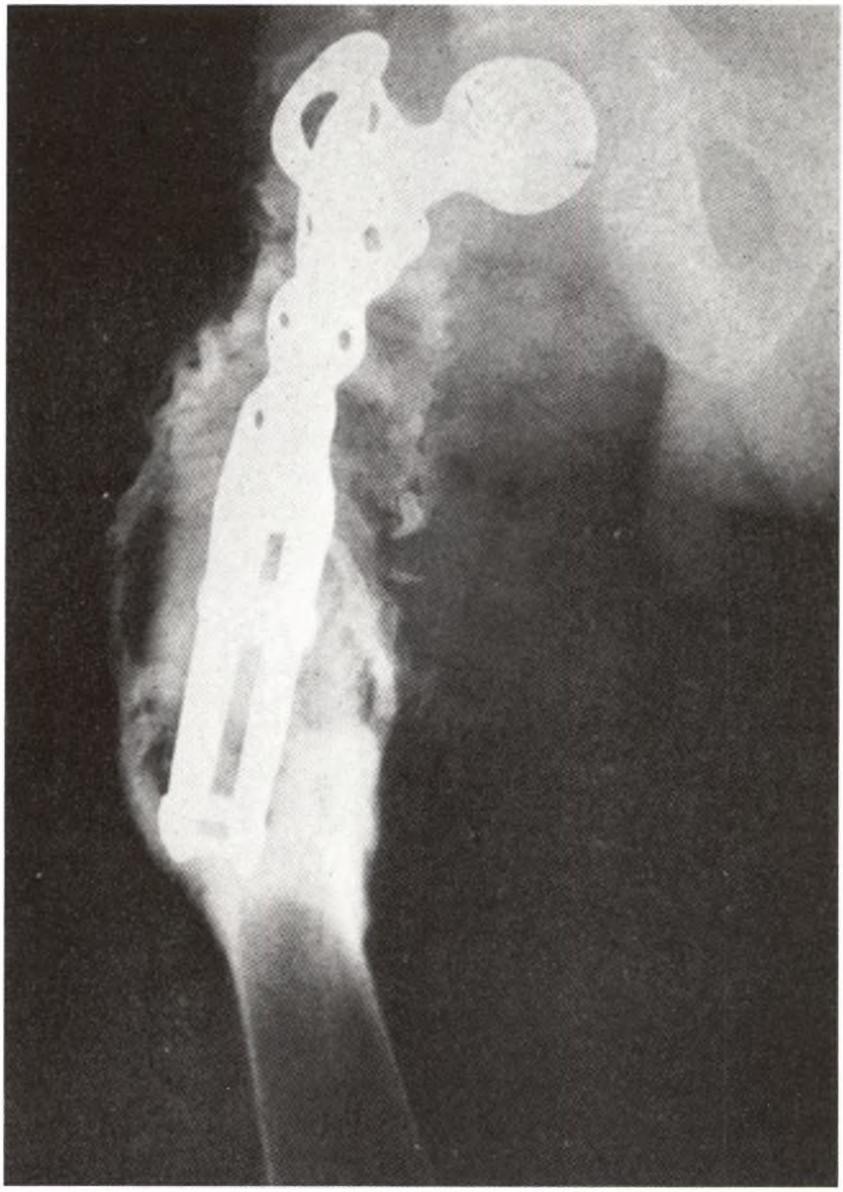


Figure 11.31 The use of a metallic prosthesis to reconstruct the upper end of the femur following a resection of a giant-cell tumor. From Austin T. Moore and Harold R. Bohlman, "Metal Hip Joint: A Case Report," *J Bone Joint Surg* 25(1943): 690.

On the basis of his experience, Enneking believed that the chief indication for their use was in the elderly, since the long-term results, because of loosening and fatigue fracture, were in doubt.[98] The technique and results of the local resection of bone tumors and the reconstruction of the resulting defects were well summarized in two symposia.[99]

The treatment of sarcomas arising in the soft tissues has been difficult because of problems in establishing a correct diagnosis and because of the tendency for local recurrence of the tumors following excision. Progress in this area has resulted more from efforts to educate surgeons in the proper procedures to be per-

Figure 11.32 George T. Pack (1898–1969). Courtesy of Irving M. Ariel.

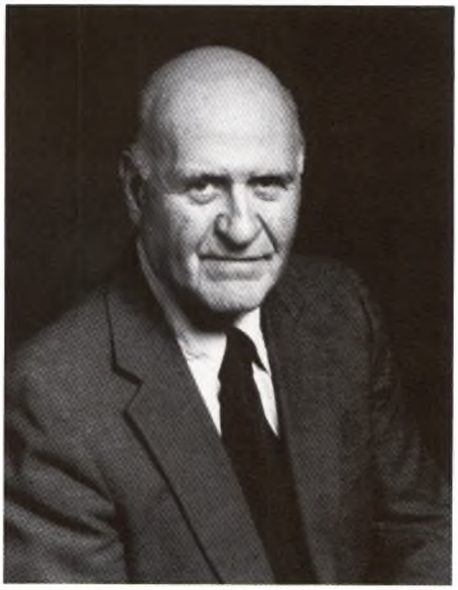


Figure 11.33. Irving M. Ariel (b. 1911). Courtesy of Irving M. Ariel.

formed than in developing the procedures themselves. The leaders of this educational effort have been George T. Pack (1898–1969) and Irving M. Ariel (b. 1911) of New York (figures 11.32–11.33). By emphasizing the wide three-dimensional local excision, the excision of the entire muscle or muscle group involved, and excision and dissection in continuity, they have taught surgeons methods that have improved the long-term results of conservative treatment of these tumors. Their views, expressed in many publications, are summarized in their great monograph.[100]

Amputations have been carried out for centuries, beginning with ritual mutilations in neolithic times and ending with amputations for vascular disease, infection, and open fractures. However, elective major amputations for tumors prior to the development of anesthesia and antiseptic-aseptic techniques were unusual. Russell C. Brock gives a good account of the hip disarticulations carried out by Astley Cooper (1768–1842) (figure 11.34) in January 1824 and by James Syme (1799–1870) in September of the same year.[101] In neither of these cases are we given the diagnosis. One of Cooper's American students, Valentine Mott (1785–1865), reported a resection of the clavicle for an osteosarcoma in 1828.[102] The forequarter amputation carried out by George McClellan (1796–1847) in Philadelphia in 1838 appears to have been for a large bone tumor, probably a chondrosarcoma[103] (figure 11.35). The technique of the forequarter amputation was perfected by Paul Berger[104] (1845–1908). The operation of hemipelvectomy, or hindquarter resection, was first successfully performed by Charles Girard[105] (1850–1916) in 1895. The technique underwent further development by J. H. Pringle and Gordon Gordon-Taylor[106] (1878–1960). The techniques of these major procedures are well described by Pack and Ariel.[107] Such radical amputations have been considered necessary because of the occurance of skip metastases occurring in the bone proximal to the primary tumor and which are responsible for local recurrence of the tumor in the amputation stump.[108] The general principles that have governed the choice of an amputation level have been given by M. Campanacci and M. Laus of the Rizzoli Institute.

> *As a general rule, amputation should be performed either through the bone proximal to the joint above the tumour, or, if through the bone which contains the tumour then at least 10 centimeters proximal to the upper limit of the tumour as shown on the radiographs.*[109]

The application of cancer chemotherapy to the treatment of bone tumors was not an immediate success. It was not until the work of Norman Jaffe (b. 1933) (figure 11.36) that any real progress was reported. Jaffe, a pediatrician born, educated, and trained in South Africa, carried out his investigations at the Dana

Figure 11.34 Astley Cooper's patient following successful disarticulation of the hip. From R. C. Brock, *The Life and Work of Astley Cooper* (Edinburgh: E. & S. Livingstone Ltd., 1952), pl. 7.

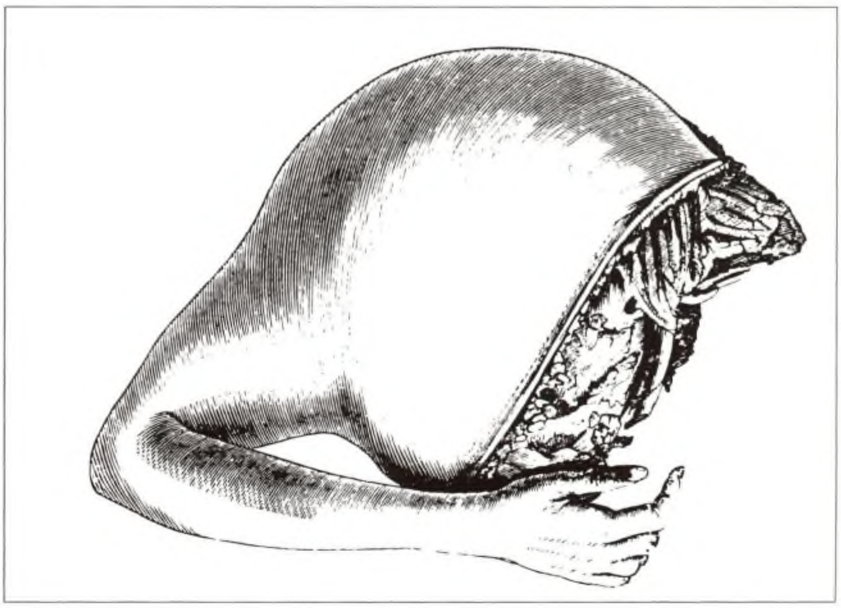


Figure 11.35 The speciman of the forequarter resection carried out by George McClellan in 1838. From George McClellan, *Principles and Practice of Surgery* (Philadelphia: Grigg & Elliott, 1848), 412, fig. 15.

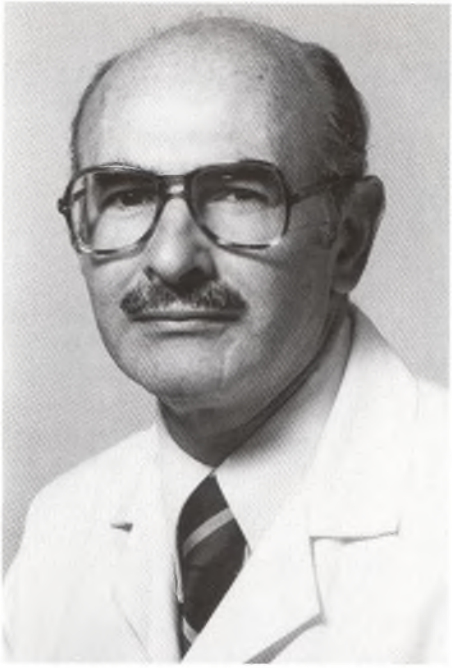


Figure 11.36 Norman Jaffe (b. 1933). Courtesy of Norman Jaffe.

Farber Cancer Institute in Boston. His paper on the use of high doses of methotrexate with citrovorum factor rescue was an important turning point in the treatment of bone sarcoma.[110] This approach to treatment was not immediately hailed as a great advance, but after several years became an essential element in the overall treatment program for patients with osteogenic sarcoma.

We can expect continued improvement in the definition of the various sarcomas of bone and soft tissue as histochemical, molecular, and chromosomal methods lead to better characterization of the malignant potential and the sensitivity to various treatment modalities. Certainly the preoperative evaluation of the patient by means of the new techniques such as computerized tomography and magnetic resonance imaging has already led to improvement in planning the surgical procedures to excise the tumors. Surgical planning now involves not simply defining the level of amputation but also consideration of the best method of limb sparing and reconstruction to provide the maximum degree of useful function. Various combinations of chemotherapy, radiation therapy, and surgical excision based on a thorough understanding of the tumor's characteristics, location, and extent can be expected to yield better long-term results for the patient.

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Conclusion

In 1845 Henry Jacob Bigelow published a small volume entitled:

Manual
of Orthopedic Surgery
Being
A Dissertation
Which Obtained
The Boylston Prize for 1844
On the Following Question:
"In what cases and to what extent is the division
of muscles, tendons, or other parts proper for
the relief of deformity or lameness?" [1]

This is the first important work on orthopedics published in the United States. The titles of its chapters indicate the nature of the specialty of orthopedics at that time. They dealt with strabismus, stammering, tenotomy, clubfoot, torticollis, false anchylosis of the knee joint, rickety knees, permanent flexion of the hip joint, anchylosis, lateral curvature of the spine, contraction of the hand and fingers, congenital dislocations, recent and chronic dislocations, and section of muscles in locked jaw. The material was based on the works of Jules Guérin, Amédée Bonnet, Alfred Velpeau, Charles Phillips, Vincent Duval, and William John Little, with whom Bigelow had visited on an extended trip abroad.

Henry Jacob Bigelow (1818–1890) (figure C.1) was born in Boston. His father Jacob Bigelow was the first professor of *materia medica* at the Harvard Medical School. After receiving his undergraduate degree from Harvard in 1837, he studied medicine with his father and with Oliver Wendell Holmes at Dart-

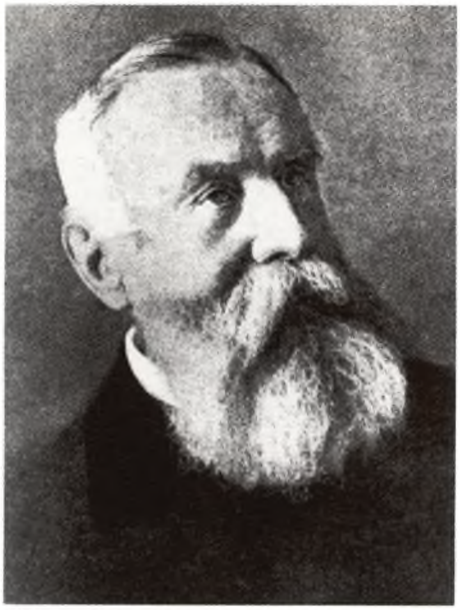

Figure C.1 Henry Jacob Bigelow (1818–1890). From *Am J Surg* 20(1933): facing p. 159.

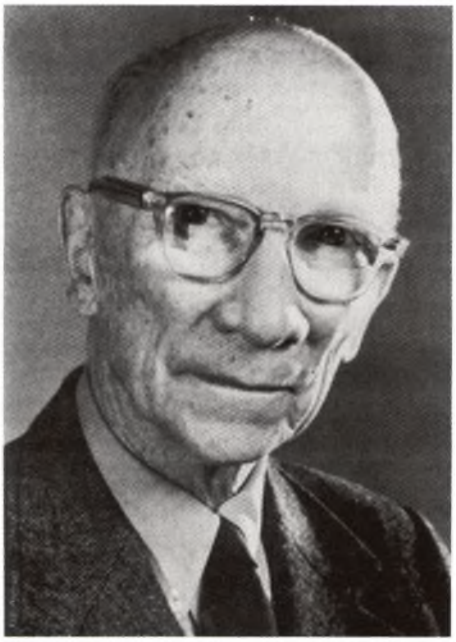

Figure C.2 Alfred Rives Shands (1899–1981). From *J Bone Joint Surg* 64A(1982): 314.

mouth. Bigelow obtained his medical degree from Harvard Medical School in 1841. He was a house officer at the Massachusetts General Hospital and traveled in Cuba and Europe. Bigelow was a brilliant personality and entrepeneur. He rapidly established himself as the leading surgeon in Boston and was the czar of the Massachusetts General Hospital for thirty years. "His character showed a union of extraordinary versatility and inventiveness with dogmatism, intolerance and lack of both progressiveness and breadth of view."[2] Present at the first operation to be carried out under ether anesthesia on 16 October 1846, he became a strong advocate of the use of this procedure. His major contribution to orthopedic surgery was his book on the mechanism of fractures and dislocations of the hip, published in 1869.[3]

The *Handbook of Orthopaedic Surgery*, written by A. R. Shands and R. B. Raney and published in 1937, shows what great changes had occurred in what was considered to be the field of orthopedic surgery during the first half of the twentieth century and at the same time, the persistance of many of the same problems that concerned Bigelow.[4] Congenital deformities, chronic bone diseases, especially tuberculosis of the spine and extremities, pyogenic infections, chronic arthritis, poliomyelitis, and bone tumors are given great attention. There is only a short chapter on fracture deformities.

Alfred Rives Shands, Jr., (1899–1981) (figure C.2) was born in Washington, D.C., where his father was a distinguished orthopedic surgeon.[5] He was educated at the University of Virginia, receiving his medical degree in 1922. His postgraduate training in orthopedic surgery was obtained at Johns Hopkins Hospital. After a short period in private practice, Shands went to Duke University in 1930 as professor of orthopedics and founded the Department of Orthopaedic Surgery. In 1937 he moved to Wilmington, Delaware, to become the director of the Alfred I. DuPont Institute, a position he retained until his retirement in 1969. During World War II he was a consultant to the United States army air force. His work was directed primarily toward the care of crippled children, but his influence on the profession at large was very great through his activities in the American Orthopaedic Association and the American Academy of Orthopaedic Surgeons. He worked tirelessly to raise funds for research and was a strong supporter of the Orthopaedic Research Society, of which he was a founding member. The *Handbook of Orthopaedic Surgery*, written in collaboration with Richard Beverly Raney (1906–1991), a colleague at Duke University, went through many editions and had wide acceptance as a standard textbook for medical students.

Orthopedic surgery has undergone more rapid changes in the past fifty years than in the one hundred years separating Bigelow and Shands. One of the most important has been the incorpora-

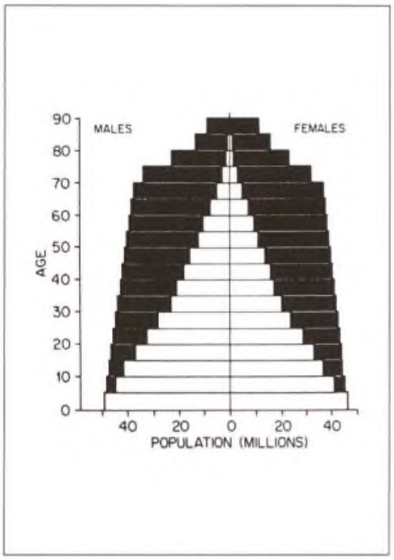

Figure C.3 Chart contrasting the idealized life expectancy of the population with the actual life expectancy of a third-world country.

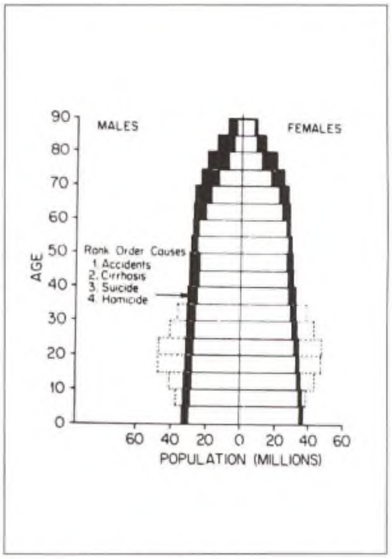

Figure C.4 Chart contrasting the idealized life expectancy of the populaton with the actual life expectancy in the United States. From J. V. Maloney, "The Limits of Medicine," *Ann Surg* 194(1981): 247–55.

tion of the treatment of fractures into orthopedic surgery. Prior to World War II, fracture treatment was the responsibility of general surgeons, and those individuals who specialized in the treatment of fractures, such as Lorenz Böhler (1885–1973), considered themselves to be general surgeons. Following World War II, general surgeons abandoned this area of specialization; their place has been taken by orthopedic surgeons. While the importance of trauma has grown, crippling due to infections and to deficiency diseases has declined. Two important factors affecting orthopedic surgery greatly have been developments in technology and changes in demographics.

While orthopedic surgeons are well aware of the changes brought about by biomechanical design, improved materials, and the applications of computer technology, fiber optics, and television to operative surgery, less attention has been given to the changes in the demographics of orthopedic patients. James V. Maloney, Jr., (b. 1925) in his presidential address to the American Surgical Association in 1981 entitled "The Limits of Medicine," contrasted the actual population structure with the idealized population structure of both a third-world country and the United States (figures C.3 – C.4). These charts indicate that as control of disease becomes more successful, more and more of the population live out their life expectancy. While the prolonging of life has come close to its limits in some countries, the goal of improving the quality of life for the aging population remains to be achieved. It is here that the future of orthopedic surgery lies. Because of their specialization in the treatment of diseases of the locomotor system, orthopedic surgeons can prevent progressive crippling, restore lost function in joints, and preserve mobility in patients whose activities would otherwise be severely limited.

Notes

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