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MEDICINE AND TECHNOLOGY IN CANADA

1900–1950

Allison Kirk-Montgomery
Shelley McKellar

CANADA SCIENCE AND TECHNOLOGY MUSEUM
MUSÉE DES SCIENCES ET DE LA TECHNOLOGIE DU CANADA
Canada

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16

Medicine and Technology in Canada

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Allison Kirk-Montgomery
Shelley McKellar

Canada Science and Technology Museum
Musée des sciences et de la technologie du Canada
Ottawa, Canada
2008

Library and Archives Canada Cataloguing in Publication

Kirk-Montgomery, Allison, 1951–
McKellar, Shelley, 1967–

Medicine and technology in Canada, 1900–1950 / Allison Kirk-Montgomery, Shelley McKellar.

(Transformation series = Collection Transformation ; 16)
Includes bibliographical references and index.
Prefatory material in English and French.
ISBN 978-1-100-10785-1
Cat. no.: NM33-1/16E

1. Medical innovations—Canada. 2. Medical innovations—Canada—History.
3. Medical technology—Canada. 4. Public health—Canada. I. McKellar, Shelley,
1967– II. Canada Science and Technology Museum III. Title. IV. Series:
Transformation series (Ottawa, Ont.) ; 16

R855.5.C36 K57 2008 610.971 C2008-980329-9

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www.sciencetech.technomuses.ca

Printed in Canada

Imprimé au Canada

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Abstract

Over the past two centuries, technology has played a significant role in the understanding, diagnosis, and treatment of disease in Canada. Technology — in the form of instruments, devices, machines, drugs, and systems — has aided medical science, altered medical practice, and changed the illness experience of patients. Nineteenth-century medical technology consisted of predominantly surgical and diagnostic instruments used by individual practitioners. By the twentieth century, large, hospital-based technologies operated by teams emerged as powerful tools in the identification and management of disease.

This volume examines various technological developments in Canadian medicine from 1900 to 1950. Our selection of diseases, research initiatives, and medical treatments highlights larger patterns in medicine, identifies Canadian contributions, and considers the impact of these innovations on Canadian society. In this fifty-year period, public health initiatives limited the spread of contagious diseases and addressed the problem of impure water and milk. Medical practitioners used X-rays to diagnose tuberculosis and to treat cancer. The discovery of insulin in Toronto in 1921–22 offered a management therapy for diabetes patients, who were otherwise facing certain death. Artificial limbs, kidney machines, and iron lungs were developed as mechanical replacements for damaged body parts. The use of technology in treating heart disease, which was emerging as a leading killer of Canadians, was manifested in blood pressure tests, electrocardiographs, pacemakers, and defibrillators. Did new medical technologies translate into improved health for Canadians? Were there not limits in the use of technology in medicine? This study explores these questions.

The development, diffusion, and adoption of (and sometimes resistance to) new technologies is historically contingent, thereby necessitating the examination of the larger political, economic, and social context. This study of medicine and its technology attempts to balance discussion of the technological development of devices and the larger meanings of medical technology's diffusion and adoption. Further, this narrative of social and material history highlights the Canadian experience. Due to the adoption of new medical technologies, many other changes occurred, including a shift in the site of health care delivery, the emergence of new medical specialties and technicians, a different (arguably "troubling") doctor-patient relationship,

Résumé

Au cours des deux derniers siècles, la technologie a joué un rôle important dans la compréhension, le diagnostic et le traitement des maladies au Canada. La technologie – sous forme d'instruments, d'appareils, de machines, de médicaments et de systèmes – a permis d'aider la science médicale, de modifier les pratiques médicales et de changer l'expérience des patients face à la maladie. La technologie médicale du XIX^{e} siècle était principalement constituée des instruments de chirurgie et de diagnostic utilisés par les praticiens exerçant seuls. À partir du XX^{e} siècle, les technologies volumineuses en milieu hospitalier utilisées par des équipes sont devenues de puissants outils pour déterminer et gérer la maladie.

Le présent ouvrage raconte l'évolution technologique de la médecine canadienne survenue entre 1900 et 1950. Notre sélection de maladies, d'initiatives de recherche et de traitements médicaux met en évidence les tendances plus générales en médecine et permet de recenser les contributions canadiennes et d'examiner l'incidence de ces innovations sur la société canadienne. Au cours de ces 50 années, les initiatives de santé publique ont limité la propagation des maladies contagieuses et permis de résoudre le problème de l'eau et du lait impurs. Les médecins praticiens ont utilisé les rayons X pour diagnostiquer la tuberculose et traiter le cancer. La découverte de l'insuline à Toronto, en 1921-1922, a donné lieu à une thérapie de gestion de la maladie aux patients diabétiques, qui autrement étaient voués à une mort certaine. La mise au point de membres et de reins artificiels ainsi que de poumons d'acier a permis le remplacement de parties anatomiques endommagées par des systèmes mécaniques. L'emploi de la technologie pour le traitement des cardiopathies, qui devenaient la principale cause de mortalité chez les Canadiens, s'est manifesté par des tests de contrôle de la pression artérielle, des électrocardiographes, des stimulateurs cardiaques et des défibrillateurs. Les nouvelles technologies médicales ont-elles permis d'améliorer la santé de la population canadienne ? L'utilisation de la technologie en médecine ne connaissait-elle aucune limite ? Voilà les questions que nous abordons dans la présente étude.

Le développement, la diffusion et l'adoption de nouvelles technologies (et parfois la réticence à celles-ci) sont étroitement liés à l'Histoire et doivent de ce fait être examinés en tenant compte du contexte politique, économique et social en général. Par cette étude de la médecine et de sa technologie, nous visons à examiner

and more. Optimism in technological solutions abounded in the first half of the twentieth century. Challenging this, however, was the continued failure of technology and other interventions to "cure" some of the most destructive illnesses and diseases. Nonetheless, as a result of technological developments in medicine during this period, practitioners gained diagnostic capabilities and individual patients benefited from some therapeutic solutions. In Canada, public health initiatives demonstrated this country's increased efforts to fight disease and safeguard the health of individual Canadians.

aussi bien le développement technologique des dispositifs que le sens plus profond de l'adoption et de la diffusion de la technologie médicale. En outre, ce récit de l'histoire sociale et de la culture matérielle met en lumière l'expérience canadienne. L'adoption de nouvelles technologies médicales a provoqué de nombreux autres changements, notamment un déplacement de l'endroit où sont dispensés les soins de santé, l'apparition de nouvelles spécialités médicales et de techniciens, la naissance d'une relation différente (pouvant être qualifiée de « troublante ») entre le médecin et son patient, et bien d'autres choses. Au cours de la première moitié du XX^{e} siècle, un optimisme débordant entourait les solutions technologiques. Toutefois, la technologie et autres interventions n'ont jamais pu « guérir » certaines des maladies les plus destructrices. Néanmoins, l'évolution technologique de la médecine survenue durant cette période ont permis aux praticiens d'accroître leurs capacités de diagnostic et aux patients de bénéficier de certaines solutions thérapeutiques. Au Canada, des initiatives en santé publique ont mis en évidence les efforts accrus du pays pour combattre la maladie et protéger la santé de chaque citoyen et chaque citoyenne.

Foreword

Canadians are exposed to medical technology daily. It is a fundamental part of our experience. Yet surprisingly, few historians have written about the history of medical technology in Canada. We can learn about present health care concerns by carefully questioning our past. How have Canadians reacted to new technologies over the years? How has the doctor-patient relationship changed with the introduction of medical technologies? How have Canadians from all regions been affected by medical technology (e.g., by changes in the cost of and access to medical procedures)? How have innovative medical technologies developed in Canada? How have physicians used these technologies? How have technologies shaped medical practice and hospitals?

Allison Kirk-Montgomery and Shelley McKellar have produced the first comprehensive survey of this topic. Aside from being an invaluable resource for researchers, students, and teachers, *Medicine and Technology in Canada, 1900–1950* provides the Canada Science and Technology Museum with a foundation for collecting and researching medical technology. Each chapter describes the personalities, places, events, and technologies associated with various themes, from early family practice to the introduction of X-rays to the insulin breakthrough to the massive postwar changes in Canadian medicine. Kirk-Montgomery and McKellar's survey will enable curators at the CSTM to build a collection that reflects and adds to this history. It will also serve as a guide for our acquisition of archival documents, photographs, and trade literature, helping us assemble a robust national resource on this topic.

Our long-term goal is to build a collection that not only informs Canadians about our medical past, but also challenges them to think about medicine and history in new ways. Artifacts, which come in so many styles, colours, designs, materials, and smells(!), are evocative vehicles for the creative historical imagination. They take us into alternative historical spaces — laboratories, workshops, factories, medical clinics, surgical theatres, doctors' offices, and companies — pointing to themes, questions, and ideas that depart from the norm. The result, in collaboration with the present study, is a broader, enriched understanding of a crucial aspect of Canadian history.

David Pantalony, Ph.D.
Curator of Physical Sciences and Medicine
Canada Science and Technology Museum
Ottawa, Ontario, 2008

Avant-propos

La population canadienne côtoie quotidiennement la technologie médicale, cette partie essentielle de notre vie. Pourtant, fait surprenant, peu d'historiens ont raconté l'histoire de la technologie médicale au Canada. Nous pouvons en apprendre sur les préoccupations actuelles dans le domaine des soins de santé en interrogeant rigoureusement notre passé. Comment les Canadiens ont-ils réagi à l'égard des nouvelles technologies au fil des années ? Quel effet a eu l'introduction des technologies médicales sur la relation entre le médecin et son patient ? Quelles ont été les incidences de la technologie médicale sur les Canadiens des différentes régions (par exemple les changements dans le coût des actes médicaux et l'accès à ceux-ci) ? Comment les technologies médicales novatrices se sont-elles développées au Canada ? Comment les médecins ont-ils vraiment utilisé ces technologies ? De quelle manière les technologies ont-elles façonné les pratiques médicales et les hôpitaux ?

Allison Kirk-Montgomery et Shelley McKellar ont mené à bien la première étude complète sur ce thème. En plus de constituer une ressource inestimable pour les chercheurs, les étudiants et les enseignants, *La médecine et la technologie au Canada, 1900-1950* apporte au Musée des sciences et de la technologie du Canada une base pour alimenter sa collection sur la technologie médicale et faire des recherches sur le sujet. Chaque chapitre décrit les personnalités, les lieux, les événements et les technologies liés à différents thèmes, qui vont des débuts de la médecine familiale à l'introduction des rayons X, en passant par la découverte capitale de l'insuline et les changements considérables qu'a connus la médecine canadienne de l'après-guerre. L'étude de Kirk-Montgomery et de McKellar permettra aux conservateurs du Musée des sciences et de la technologie du Canada de constituer une collection qui reflète cette histoire et qui l'enrichit. Elle nous guidera également dans nos acquisitions de documents d'archives, de photographies et de catalogues de fabricants, ce qui nous aidera à constituer une solide ressource nationale sur le sujet.

Notre but à long terme est de bâtir une collection qui non seulement renseigne les Canadiens sur l'histoire de la médecine du pays, mais qui aussi les incite à voir la médecine et son histoire sous un autre jour. Les artefacts, avec leurs styles, leurs couleurs, leurs formes, leurs matériaux et leurs odeurs si variés, sont des moyens efficaces de réveiller l'imagination historique. Ils nous emportent vers d'autres espaces historiques –

laboratoires, ateliers, manufactures, cliniques médicales, salles d'opération, cabinets de médecin et entreprises – mettant en lumière des thèmes, des questions et des idées qui s'écartent de la norme. Le résultat en association avec la présente étude s'avère l'enrichissement et l'élargissement de notre connaissance d'un aspect essentiel de l'histoire canadienne.

David Pantalony, Ph.D.
Conservateur, Sciences physiques et médecine
Musée des sciences et de la technologie du Canada
Ottawa (Ontario) 2008

Acknowledgments

In 2003, Randall Brooks, Ph.D., Director, Collection and Research Division at the Canada Science and Technology Museum, invited us to write an historical assessment of technological developments in Canadian medicine during the first half of the twentieth century. This assessment was to serve as a resource to Museum staff as well as to curators elsewhere in the development of their medical collections and possible exhibition themes. Faced with a donor wanting to drop off granddad's medical equipment or reading about the retirement of a prominent medical researcher, could Museum staff be guided by such a document in their task of safeguarding our medical past? It was a challenging undertaking for two medical historians both to delve into the material culture of medicine (what objects warrant deposit in a national museum?) and to synthesize the history of medicine and technology in Canada (how do we situate these objects within their historical context?). We thank Randall for this initial opportunity and for his guidance, five years later, in publishing this work.

We were fortunate to be able to work with several other individuals at the Canada Science and Technology Museum. Thank you to David Pantalony, Ph.D., Curator of Physical Sciences and Medicine, for reviewing our manuscript and making several helpful suggestions. We also appreciate CSTM archivist Marcia Rak's assistance with images and the copy-editing skills of Naomi Pauls. Charles Roland, Hannah Professor in the History of Medicine (Emeritus) at McMaster University, kindly served as the external reviewer of our manuscript for the Museum. We thank him for his comments.

Researchers dare not forget to acknowledge the assistance of librarians, archivists, and colleagues. We could not do our work otherwise, and this was certainly the case here. We thank individuals at the following institutions for their interest and help during the course of this project: City of Toronto Archives, Glenbow Archives, Library and Archives Canada, Université de Montréal Archives, City of Vancouver Archives, Lung Association of Saskatchewan, University of Toronto Thomas Fisher Rare Book Library, Sanofi Pasteur Limited, Canadian Museum of Civilization, Toronto's Hospital for Sick Children Archives, March of Dimes Canada Archives, the Archives of Ontario, *Canadian Medical Association Journal* Archives, the Smithsonian's National Museum of American History (U.S.), and the Science Photo Library (U.K.). Thank you to Larry McNally, Ph.D., at Library and Archives

Remerciements

En 2003, Randall Brooks, Ph.D., directeur, Conservation et recherche, au Musée des sciences et de la technologie du Canada, nous a demandé de rédiger une évaluation historique de l'évolution technologique de la médecine canadienne au cours de la première moitié du XX^{e} siècle. Cette évaluation devait servir de ressource au personnel du Musée et aux conservateurs d'autres établissements pour élaborer leurs collections médicales et des thèmes possibles d'exposition. Face à une personne souhaitant faire don de l'équipement médical de son grand-père ou à l'annonce de la retraite d'un éminent chercheur en médecine, le personnel du Musée pourrait-il utiliser un pareil document comme guide dans son travail de préservation de notre passé médical ? Ce fut une expérience exaltante pour les deux historiennes de la médecine que nous sommes de fouiller dans la culture matérielle de la médecine (quels objets méritent une place dans un musée national ?) et de synthétiser l'histoire de la médecine et de la technologie au Canada (comment situer ces objets dans leur contexte historique ?). Cinq ans après que Randall Brooks a fait appel à nous, nous le remercions d'avoir été l'investigateur de ce projet et de nous avoir offert ses précieux conseils dans la publication de cet ouvrage.

Nous avons eu la chance de pouvoir travailler avec plusieurs autres personnes du Musée des sciences et de la technologie du Canada. Nous remercions David Pantalony, Ph.D., conservateur, Sciences physiques et médecine, pour avoir révisé notre manuscrit et formulé plusieurs suggestions utiles. Nous sommes également reconnaissantes à l'archiviste du Musée, Marcia Rak, qui nous a aidées pour les images et à Naomi Pauls pour ses compétences en révision. Le D^{r} Charles Roland, professeur émérite, qui occupe la chaire Jason A. Hannah d'histoire de la médecine à l'Université McMaster, a aimablement accepté d'être le lecteur externe de notre manuscrit pour le Musée. Nous le remercions pour ses commentaires.

Bien sûr, les chercheuses n'oublient pas de remercier les bibliothécaires, les archivistes et les collègues pour leur soutien. Notre travail ne serait pas possible sans ces personnes, et leur aide a été particulièrement appréciable pour cet ouvrage. Nous remercions les personnes des institutions citées ci-après pour l'intérêt et l'aide qu'elles nous ont apportés pendant la réalisation de ce projet : archives de la Ville de Toronto, archives de Glenbow, Bibliothèque et Archives Canada, archives de l'Université de Montréal, archives de la Ville de Vancouver, Lung Association of Saskatchewan,

Canada for drawing our attention to Hopps' autobiography; to Chris Rutty, Ph.D., for providing images of Connaught Laboratories through Sanofi Pasteur Limited; and to Charles Hayter, MD, for assistance with photos related to radium treatment.

Those who assisted us in the production of this volume are certainly not to be held responsible for any of our interpretations, errors, or omissions. We do hope that this volume will be used as initially intended, that is, as a resource to assist Museum staff as well as other curators, researchers, or instructors engaged in the history of medicine and technology in Canada.

Allison Kirk-Montgomery, Ph.D.
Toronto, February 2008

Shelley McKellar, Ph.D.
London, February 2008

bibliothèque des livres rares Thomas Fisher de l'Université de Toronto, Sanofi Pasteur Limitée, Musée canadien des civilisations, archives de l'Hospital for Sick Children de Toronto, archives de March of Dimes Canada, Archives publiques de l'Ontario, archives du *Journal de l'Association médicale canadienne*, Smithsonian's National Museum of American History (États-Unis) et Science Photo Library (Royaume-Uni). Nous remercions Larry McNally, Ph.D., de Bibliothèque et Archives Canada, pour avoir attiré notre attention sur l'autobiographie de Hopps, et aussi Chris Rutty, Ph.D., qui nous a fourni des images des laboratoires Connaught par l'intermédiaire de Sanofi Pasteur Limitée. Enfin, merci à D^{r} Charles Hayter pour son aide concernant les photos sur la radiumthérapie.

Celles et ceux qui nous ont soutenu dans la production de cet ouvrage ne peuvent en aucun cas être tenus responsables de nos interprétations, erreurs ou omissions. Nous espérons de tout cœur que cet ouvrage sera utilisé conformément à son but initial, c'est-à-dire comme une ressource visant à aider non seulement le personnel du Musée mais aussi d'autres conservateurs, chercheurs ou formateurs intéressés à l'histoire de la médecine et de la technologie au Canada.

Allison Kirk-Montgomery, Ph.D.
Toronto, février 2008

Shelley McKellar, Ph.D.
London, février 2008

Introduction

Historically, medical technology has played a significant role in furthering understandings of disease and providing improved methods of diagnosis and enhanced therapeutics for patients. Moreover, the technology of medicine has altered (and arguably continues to alter) the practice of medicine. It changed not only how the medical community approached and treated illness but also the ways doctors and patients related to each other. Nineteenth-century medical instruments — such as the stethoscope, laryngoscope, and ophthalmoscope — were predominantly the tools of the individual medical practitioner. In contrast, twentieth-century medical technology — like the X-ray machine, electrocardiograph, and ventilators — constituted large, expensive equipment purchased by hospitals and used by teams. Such technological change was significant, contributing substantially to the rise of the hospital as the preferred place of treatment in this period, to the systematization of health care, and to the emergence of medical technology specialists. With the groundbreaking works of Audrey Davis and Stanley Joel Reiser, historians began to appreciate how developments in medical technology could illuminate other facets of the history of medicine.[1]

Technological innovations emerged alongside new approaches in medical science as laboratory science and medical practice became more intertwined in the twentieth century. Historians of science, interested in the social history and process of discovery as much as or more than the content of technology, have begun to debate the relationship between pure science and applied discovery, and recently have argued that the rigid distinction between these phases is false.[2]

Further, the development, diffusion, and adoption of (and sometimes resistance to) new technologies is historically contingent, neither inevitable nor necessarily linear. Traditional scholarship presented technological developments as a one-way progression from invention through innovation to diffusion, starting with laboratory research and moving out through clinical applications. Today most historians agree that the process is iterative and multidirectional.[3] Scholars including John Pickstone, Illana Lowy, Jennifer Stanton, Ruth Schwartz Cowan, Joel Howell, and others also challenged the common assumption that medical innovations were adopted because they were superior.[4] Rejecting technological determinism, they argue that the historical context (material, political, economic, ideological, and social) is significant in understanding the greater implications of new technologies. Indeed, technology is imbued with social meanings, meanings that are attributed to, not inherent in, technologies.[5] Utilizing these themes, our study of medical practice and its technology draws on the study of material culture and on social history: it addresses technological and social aspects of device development and adoption, highlighting the Canadian experience.

This volume examines aspects of technological development in Canadian medicine from 1900 to 1950. Following recent discussions in the history of medicine, technology is defined broadly, as the instruments, devices, machines, drugs, and systems developed for medical research and/or for clinical practice. The history of medical technology is an international story, but wherever possible, Canadian exceptionalism is emphasized and discussed. This study draws attention to technological innovations in medicine developed by Canadians as well as to the changing nature of medical practice and patient experience in Canada as a result.

Our historical assessment began as a research resource to assist curators at the Canada Science and Technology Museum in collection development. It identifies those medical technologies developed or utilized in Canada and describes their place in the broader context of the history of health and medicine. Although it is not an exhaustive review, it attempts to highlight key Canadian innovators, clinicians, sites, patients, and artifacts as a guide for curators and researchers in their work, and it points to sources for further reading.

This volume contains eight thematic chapters, roughly chronological, focusing on selected diseases, medical research initiatives, and/or clinical practices associated with specific medical technologies. Connecting these chapters are several overarching themes. One is the changing site of health care and professional knowledge. That is, at the turn of the twentieth century, the home and the doctor's office were centres of diagnosis and therapy and, to some extent, innovation. By 1950, this had changed; the laboratory had become the new site of diagnostics, and the hospital was the prevailing site of treatment and innovation. A second theme is the shift from nineteenth-century medical instruments and clinical "arts" to the twentieth-century "science" of medical machines, procedures, and equipment. Third, the function of instrumentation expanded during this period from tools for surgery and diagnosis,

their main nineteenth-century purposes, to devices of therapy. This shift in function contributed to the growth of medical specialties and shaped the role of medical technicians. A fourth theme addresses the changing doctor-patient relationship as a result of technological mediation and the challenge of access and inequity in treatment. A fifth theme addresses the impact of war on medicine, with this study focusing specifically on government funding of medical research in wartime and some innovations on the battlefield.[6] Lastly, despite a growing optimism in technological solutions and the emergence of the technological imperative in medicine, a major continuity in this period is the failure of technology and other interventions to "cure" some of the most destructive illnesses and diseases.

This descriptive study of medical technology, highlighting selected devices and practices in Canada from 1900 to 1950, is based mainly on a synthesis of secondary sources, with the inclusion of selected primary source material. Medical technology of the past was once of interest mainly to doctors, scientists, and antiquarians, but it is now a vigorous field of social and popular history. However, there is no monograph on the history of medical technology in Canada. More surprisingly, there is only one slim, though useful, overview of the general history of medicine in this country.[7] Though works cited in the bibliography will resonate with observers of the Canadian experience, they tend to focus on the American scene. A notable exception is Jacalyn Duffin's *History of Medicine*, a brief historical survey of Western medicine, in which Canadian medical contributions are discussed.[8] Many good monographs, articles, and theses exist on specific individuals, diseases, institutions, events, or themes in the history of Canadian medicine and technology. The thickness of and range of works cited in Charles Roland's two-volume bibliography, *Secondary Sources in the History of Canadian Medicine*,[9] demonstrate that our own historiography of medicine is growing rapidly in both quality and quantity. Yet in that same sourcebook, there is no entry for "technology," and only a few monographs and articles that deal specifically with technology are listed under particular medical specialties and disease entities. We have relied heavily on the work of other historians, as will be apparent by our endnotes, and we have included an extensive bibliography of monographs, collections, and websites for further reading.[10] We hope that this synthesis will encourage further study in this important subfield of medical and Canadian history.

Notes

1. Stanley J. Reiser, *Medicine and the Reign of Technology* (New York: Cambridge University Press, 1978); Audrey B. Davis, *Medicine and Its Technology: An Introduction to the History of Medical Instrumentation* (Westport, Conn.: Greenwood Press, 1981).
2. An underlying theme of Jennifer Stanton, ed., *Innovations in Health and Medicine: Diffusion and Resistance in the Twentieth Century* (London: Routledge, 2002).
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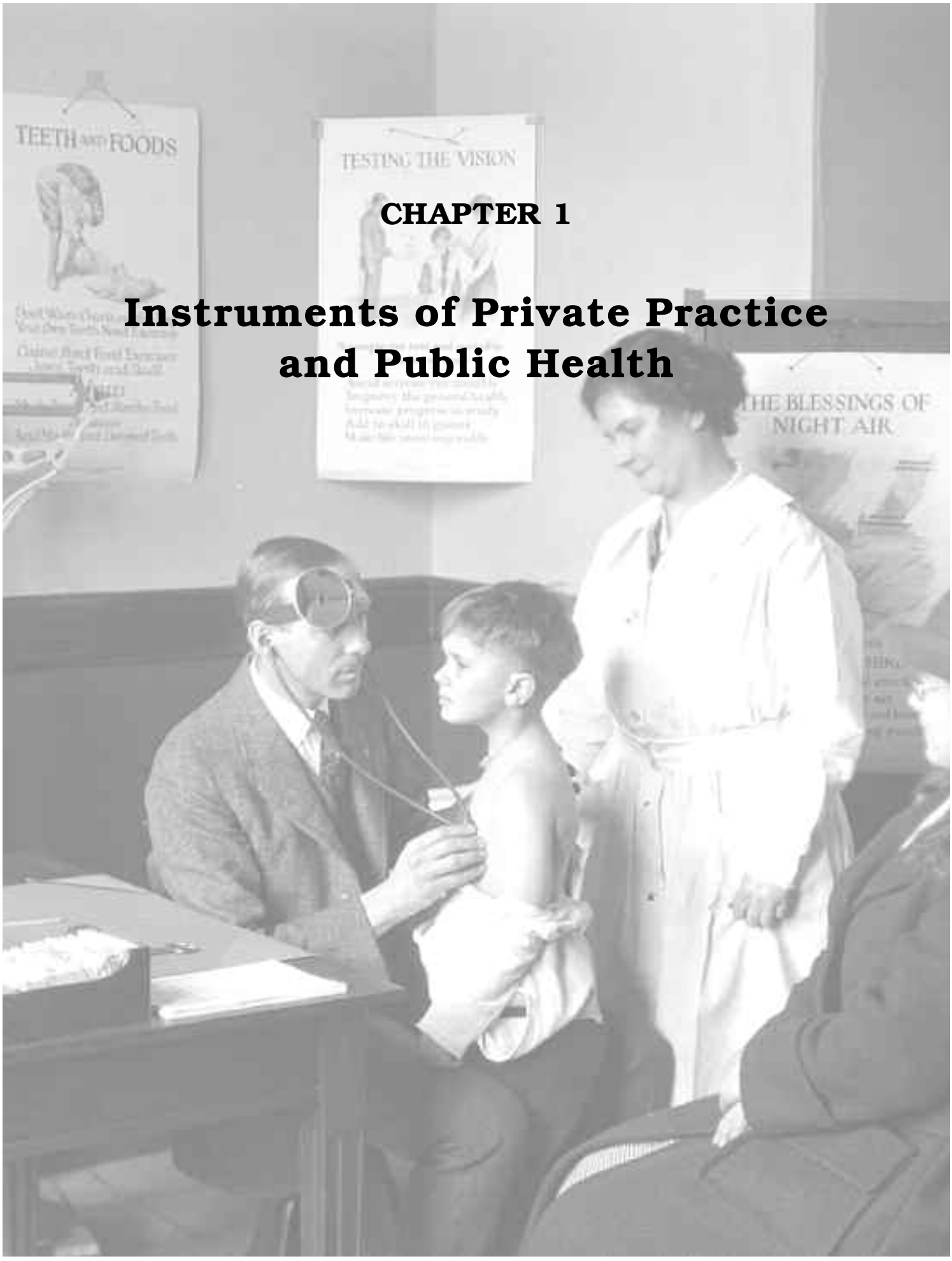

CHAPTER 1

Instruments of Private Practice and Public Health

Instruments of Private Practice and Public Health

In 1900, although Prime Minister Wilfrid Laurier spoke optimistically about Canada's future in the twentieth century to come, Canadians dreaded illness and death in friends and family. The mortality rate in the early twentieth century was nearly three times higher than it was a century later: in 1914, it was approximately 18 per 1,000,[1] compared to 6.6 per 1,000 in 1997.[2]

The main culprits were infectious and contagious diseases, especially tuberculosis, typhoid fever, influenza, and diphtheria.[3] In the past, as today, disease struck unevenly across age, class, ethnic, cultural, and territorial divisions. The burden of early death fell most heavily on city dwellers, Native people, and children. Among the last,15 percent died before their first birthday. In almost all cases of disease outbreaks, the young were overrepresented in the statistics of death. In 1918, the Spanish influenza pandemic killed an estimated fifty thousand, a staggering figure that rivalled the number of young men who died in action in the First World War. A few cities were hot spots of disease. In the first years of the twentieth century, among European and North American cities, Winnipeg was plagued with the highest rate of infection from typhoid fever, while Montreal was "the most unhealthy city in North America," particularly for francophones, because of its high incidence of tuberculosis and high rate of infant mortality.[4] Non-contagious and chronic conditions such as cancer, kidney disease, and heart disease also figured heavily in death certificates. Beyond the mortal illnesses, many people endured chronic disability such as arthritis and respiratory illness that limited their lives and condemned them to poverty. In the decades before medicare and hospital insurance, families could be bankrupted by the costs of illness and medical treatment.

Until the discovery of sulpha drugs and antibiotics between the First and Second World Wars, knowledge about the body — gained in the hospitals, morgues, and laboratories of Europe — far outstripped the ability of clinical science to cure, and neither institutions nor technology could change the outcome of most disease and illness. Although there were hospitals in all provinces and in most cities of Canada by 1900, they were not modern curative institutions but custodial places of last resort for the dying poor.[5] Most sick people opted to stay at home and relied on the women of the family for nursing, supplemented with a doctor's visit if they could afford it. They trusted in prayer, or in the body's ability to heal itself, or in the relief that would come with the passage of time, and most people survived most illnesses.

There were exceptions to medical impotence, particularly in surgery, the specialty that had gained the most from gory practice on the battlefields of the nineteenth century. Advances in surgery and anaesthesia could prevent death from acute illnesses such as appendicitis. Intervention in difficult childbirth saved some mothers and infants (though it killed others). In their offices and in patients' homes, physicians employed a variety of surgical instruments to probe the body and to cut flesh and bone. Doctors could set broken bones and stitch and cauterize wounds. In general practice, cutting instruments were used most often for dental problems and for draining sites of infection. The typical family doctor's kit probably held catheters, tonsil scissors, knives, and probes, along with syringes, a stomach pump, and cannula (tubes of glass).[6] A few doctors may have had a more extensive "workshop" or kit: a "mechanical genius" named William Beaumont, a physician of Upper Canada, invented or developed a number of gynecological and surgical instruments.[7] But surgical forays inside the body were still experimental and desperate measures, generally avoided where possible because of the double dangers of infection and shock from blood loss.

Doctors, nurses, and pharmacists were able to offer some physical relief and mental comfort from the symptoms of illness. Though limited, their *materia medica* could alleviate pain through tinctures and hypodermics of opium and morphine.[8] There were powders for fever, concoctions for cough, syrups for gastric upset, tonics for nerves, and aspirin for pain. Chloral hydrate could tranquillize the uneasy in mind. Apparatus developed in the nineteenth century could ease patients' distress. Jennie Trout and Amelia Tifft of Toronto, doctors practising in the last quarter of the century, developed baths, heat lamps, and other soothing electrotherapeutic equipment that used the new galvanic batteries.[9] Physicians could also advise on dietary and behavioural adjustments that were within the control of the patient. For instance, anemia could be aided by enriched diet; tuberculosis and other lung dysfunction by rest.[10] And nurses offered skilled caring for those who could afford their services.

In some cases, the most valuable service the skilled doctor could offer to the patient was a diagnosis

(what was wrong) and a prognosis (what would happen), based on experience and the accumulation of professional knowledge about the workings of the healthy body and of the causes and paths of disease. Technology — the instruments, devices, and procedures, including the art of physical diagnosis — developed in the new medical sciences by pathologists, physiologists, chemists, and clinicians made possible this explosion of knowledge, even if treatment, at 1900, lagged behind.

This chapter begins with a discussion of three key pieces of medical technology of the late nineteenth and early twentieth century: the stethoscope, the thermometer, and the microscope. They were all important instruments of research applied to scientific study of the body in disease and health. Each was also a valuable diagnostic tool, functioning to extend the clinician's senses. All three instruments were also used to advance the goals of the public health movement that was gathering force at the turn of the century. The stethoscope, thermometer, and microscope helped to bring about new diagnostic routines at the bedside, new preventive regimes of public health, and eventually, new therapeutic directions.

The Stethoscope

In the first decades of the twentieth century, Canada's most famous expatriate was William Osler, Regius Professor of Medicine at Oxford in England, the most revered medical teacher and authority in the Western world. His personal medical services were sought not for his ability to cure but for his skills in physical diagnosis and his clinical acuity in prognosis. To Osler and his colleagues, diagnosis was a physical act; it required direct contact with the patient. "It is the business of the physician to know in the first place, things . . . which are to be perceived by the sight, touch, hearing, the nose, and the tongue, and the understanding," wrote Hippocrates,[11] and Osler agreed. At McGill and other medical schools, he taught that "the four points of a medical student's compass are: inspection, palpation [examination with the hands], percussion [tapping the body and listening to the

Figure 1. *Observed by a nurse, a Toronto public health doctor examines a boy with the aid of a stethoscope and a head mirror, two emblems of the modern twentieth-century physician, in 1923. The weigh scales and posters illustrate the twin social and medical concerns of the decade, nutrition and hygiene.*
(City of Toronto Archives)

sounds produced] and auscultation."[12] Osler considered auscultation — the art of paying attention to sounds the body produced — to be essential. To better understand the rhythms and noises of heart and lungs, even abdominal organs, Osler recommended the stethoscope.[13]

At least from the days of Hippocrates, doctors had been trying to hear and interpret the sounds of the chest by placing their ears on their patients' bodies. In 1816, the French clinician René Laennec tried to enhance his hearing with a mechanical aid. Using at first a simple cylinder of paper, and later one of wood, Laennec named his instrument the "stethoscope" from the Greek words meaning "chest" and "to explore."[14] By striking the subject's chest or other parts of the torso to create a sound (percussion), and by listening through the stethoscope to the beating heart and to the expanding and contracting lungs and to other organs (auscultation), Laennec believed he could detect illness and disease earlier, and distinguish more clearly the ailments of the patient. Though many French physicians doubted the stethoscope's ability to amplify chest sounds over what could be heard by simply laying the ear on the chest, doctors did appreciate the distance that the instrument inserted between their own persons and modest or possibly contagious patients.[15]

The stethoscope was more than a diagnostic aid for physicians. In the great hospitals and morgues of Paris, doctors employed their instruments to further science by investigating disease as the product of organ and tissue lesions. In the opinion of the historian Stanley Joel Reiser, "The stethoscope focused the attention of physicians on a new class of disease signs — the sounds produced by defective structures of the body."[16] The approved method of research started with the physician determining the signs of pathology during physical examination of the living patient, using the stethoscope and other instruments; when the patient died, the clinician-scientist would correlate these signs with the findings at autopsy on the deceased patient.[17] The stethoscope therefore became a tool that bridged pathology, the study of disease, and anatomy, the study of body structures.

Doctors reported their discoveries in journals and professional meetings so that the anatomo-pathological method, and the new medical understandings of heart and lung disease that flowed from it, spread even to the remote colonies that later came together as Canada. Only a decade after Laennec's invention, the Quebec doctor Pierre Beaubien may have brought the stethoscope from Paris to Montreal in 1827.[18] Certainly by the last quarter of the century, in Canadian morgues, in the charity hospitals, and in prisons and asylums where they took advantage of legal access to the corpses of prisoners and paupers, doctors who had used the stethoscope to identify symptoms in living patients later dissected their bodies to identify gross pathological lesions.[19]

Through the nineteenth century, the clarity and acuity of the stethoscope improved as the European manufacturers of scientific instruments, notably the Germans, responded to clinical demand.[20] The earliest stethoscope designs were monaural (with one earpiece), but by 1900 many models were binaural. The two earpieces were attached by flexible hollow tubing to a rubber-covered smooth metal tube. The tube received sound from a chest-piece that was placed on the patient's torso. After 1926, with the Sprague-Bowles double-ended receiver, the physician could hear low-frequency sounds by applying the open bell and higher-frequency sounds by using the flat diaphragm.[21]

However, mastering the stethoscope was difficult, as was teaching its use to students in the new medical schools being established across Canada. What did a particular gurgle or swoosh signify? Laennec was the first to provide an extensive terminology for sounds heard and their meanings, in an attempt to promote standard usage, but sounds are difficult to translate into words. Such a universal classification was a goal made almost impossible because of cultural differences that split the profession of medicine in the West.[22] Eager to improve the status of their profession, the professors of medical schools wanted to standardize medical knowledge and smooth its transmission to students. Leading schools such as McGill in Montreal were already developing a range of teaching aids — "lantern shows," photographs, wax models, and curator Dr. Maude Abbott's extensive collection of pathological specimens in the McGill Medical Museum. These were all useful for anatomy lessons, but they could not help students decode subtle and transient sounds that emanated from the chest of a live patient.[23]

The solution came in the form of specialized teaching apparatus, simple and sturdy stethoscopes manufactured by European precision instrument companies and designed specifically for teaching student doctors (and later, nurses). In Britain, Germany, and France, university scientists late in the nineteenth century had partnered with business entrepreneurs to launch these manufacturing companies that turned out scientific instruments. Baird and Tatlock, Harvard Apparatus Company, Cambridge Scientific Instrument Company, and C. F. Palmer were some of the main manufacturers.[24] Their stethoscopes standardized the sounds users would detect. Other teaching devices were developed to make sure teacher and student heard the same sound at the same time. For example, instructors used multi-ended stethoscopes for the instruction of students. Mechanisms that replicated

chest sounds for the classroom, and later, phonograph records of heart sounds recorded through a stethophone (a stethoscope with headphones) also helped to pass on the skills required for auscultation.

James Langstaff, a doctor in practice in Ontario for forty years until 1889, and one of the few who left detailed records of his daily practice, relied on his stethoscope for all manner of chest conditions.[25] He was not unusual. By the late century, around the Western world, the stethoscope became "scientific medicine's hallmark" and held pride of place in leather medical bags and around doctors' necks.[26]

The Thermometer

The thermometer is an example of a group of medical instruments that were used first in physiological research and later in clinical practice. If pathological anatomy was a leading medical science at the start of the nineteenth century, physiology was the rising scientific discipline by its midpoint. Experimental physiologists working in their new institutions called laboratories in Germany and France began to change concepts of and approaches to health and disease.[27] That is, while pathology focused on disease through the study of distinct structures — specific body parts and organs, cellular tissue, nerves, or blood vessels — and encouraged a view of illness as localized disease displayed through structural abnormalities of the tissues,[28] in contrast, physiology's subject was the living body: the relationships among organ systems, and the body's functions and processes over time.

Instruments that recorded and measured processes of living bodies were central to the rise of physiology. In the words of the historian Merriley Borell, "The simple act of recording rapidly transformed physiology from a primarily descriptive, vivisectional and anatomically-oriented activity to a quantitative experimental science."[29] Beginning with the kymograph for blood pressure, instruments attached to the living subject allowed physiological events to leave a graphic "autograph" that was permanent, seemed objective, and could be converted into numerical values. The necessary components for recording were a revolving drum, a pen or a scratching tool, and ink or sooted paper. The kymograph was followed by specialized sensing devices featuring drums that operated at various speeds, recording pendulums, and clockwork (later electric motor) models.

Degrees of body heat, pulse beats per minute, measurements of pressure in the blood vessels, lung capacity, blood cell counts, clarity of vision, colour sensitivity, nerve and muscle function: laboratories hummed with scientists investigating, counting, mapping, and measuring hundreds of processes. The new instruments were used on live animal and human subjects, healthy and sick. The desire to capture the workings of the body in machine-made "legible handwriting"[30] also shaped and changed the use of older instruments such as the stethoscope. Although it was used extensively in experimental physiology, the stethoscope conveyed noise, not precise numerical or graphic data. This reduced its usefulness in studies of lung function until it was teamed with the spirometer, an instrument that graphically recorded changes in the volume and speed of airflow in and out of the lungs.

One of the mainstays of the physiology laboratory was the thermometer, a centuries-old instrument that became useful to clinicians and scientists after it was coupled with a scale to provide quantitative data.[31] If the stethoscope magnified hearing, the clinical thermometer improved the physician's sense of touch. A hand on the forehead could help the doctor perceive the presence or absence of fever, but because the thermometer could differentiate temperature in smaller units or degrees, it could detect fever in the subtle early stages of an infectious illness. Clinical researchers soon realized, however, that a raw temperature reading is useless information unless it is computed against a mass of data that provides norms for sickness and health. An important contribution to thermometry, therefore, was Carl Wunderlich's 1868 publication of his analysis of temperature data on thousands of patients and his observations of the patterns of bodily temperature through the courses of thirty-two different diseases.[32] Isolating contagious illness and determining what stage of illness a patient was experiencing were major medical responsibilities; therefore, the mercury and glass instrument became an important tool for physicians. In the late 1880s, the thermometer became one of the most common instruments in doctors' bags.[33]

Acquiring the latest model was simple, for Canadian physicians could order thermometers from medical supply companies that advertised in professional journals. The best models were made in England by Casella, in the United States by Weinhagen, and in Germany by several manufacturers. (To date, historians have not identified any Canadian business ventures that could compete with the precision manufacturing capabilities of the medical and scientific instrument companies of continental Europe, England, and to some extent, the United States.)[34] Manufacturers strove for greater standardization, improved reliability, and finer calibration.[35] Thus, doctors could send their thermometers to be calibrated to the Kew Observatory in England or to the Thermometric Bureau at Yale College in the United States. These institutes were established because of the need for

precise standards in instruments used in scientific and industrial applications beyond medicine.

Refinements by the turn of the century increased the thermometer's accuracy and its ease of interpretation. The instrument became both cheaper and smaller, and accordingly was more useful for bedside practice. In 1896, a version was developed with a flat side to prevent it from rolling and breaking, and with the numbers marked on it clearly so as not to obscure the column of mercury. Other specialized thermometers were developed for particular body parts and products (ear, skull, underarm, rectum, urine). As part of a late-nineteenth-century development that applied electricity to diagnostic and therapeutic instruments, Becquerel developed a "thermo-electric differential thermometer for determining temperature differences over the body."[36]

One notable feature of thermometers since the eighteenth century is that they are self-registering, meaning that until the thermometer is shaken, the mercury remains at the maximum reading after the instrument is removed from the patient. This feature provided a safe vantage from which to observe body temperature; previously, doctors had to hover close to the possibly contagious patient to read his or her temperature. It also meant that nurses or family members of the sick person could use the instrument to take the readings, but that the interpretation of the data could be done later by the doctor.[37] Issues around the control of technology — who should use a technology and who should interpret its results — were at the core of interprofessional and intraprofessional conflicts from the early twentieth century.

Canadian doctors began to use temperature graphs (readings over time) as a valuable indicator of patient health. In hospitals, the temperature graph became a key component of the modern clinical chart. The official history of New Brunswick's Saint John Hospital notes 1888 as the date of its first graphic temperature chart.[38] Stanley Reiser has described the power of the clinical chart to consolidate medical knowledge.[39] As historians have observed, the clinical chart's focus on signs that could be measured and quantified, such as fever in the case of the thermometer, may have caused doctors to neglect other aspects of illness:[40] because the thermometer could be read independently of the presence of the patient, and because it provided objective data, doctors tended to rely less on symptoms reported by the patient. In brief, the thermometer was one of the first medical instruments to separate the doctor and the patient in time and space. In the twentieth century, this trend away from physical diagnosis, based on contact between doctor and patient, and away from diagnosis based on the patient's own illness experience as related to the doctor, continued in the development of the clinical laboratory.

The Microscope and Microscience

While nineteenth-century physiological instruments were allowing researchers to record various bodily processes, the microscope was revealing fine details of bodily tissues and, astoundingly, the tiny organisms that thronged in them. However, breakthroughs in cell anatomy and bacteriology did not immediately translate into therapeutic advances. Microscopy was the core technology around which public health and clinical laboratories were organized. The history of the microscope has received much scholarly and professional attention.[41] This section sketches its development and that of its ancillary technology.

The close examination of bodily fluids and tissues was an ancient medical practice, but not until the mid-nineteenth century, with the aid of greatly improved microscopes, could researchers begin to study organisms at the cellular level.[42] The crucial technological development occurred in the 1830s, when a passionate interest in the natural world inspired Joseph Jackson Lister, an English wine merchant, to develop the achromatic compound microscope. Using two lenses, one located at each end of the body tube, the achromatic compound microscope removed the distortion that until then had accompanied high magnification.[43] Scientifically minded Victorian Canadians who acquired early microscopes came from a variety of persuasions and were more likely to be interested in "natural history" than medicine at first. Although a few imported the gorgeous brass instruments being produced in Germany and France for wealthy amateurs, others assembled their own. In 1857, a Toronto lawyer, Patrick Freeland, invented for his microscope an improved traversing stage (the area that holds the specimen) that allowed smooth movement and therefore better scanning of the sample.[44]

The medical use of microscopes accelerated with the work of Rudolph Virchow, who utilized the microscope for his 1858 treatise on cellular pathology; his was the dominant text of the nineteenth century in the discipline of histology (or the anatomy of minute plant and animal tissues). Virchow, a German, was a leader in the international public health movement and influenced some of the first Canadian and American laboratory scientists.[45] However, the use of microscopes (and the teaching of basic science) was slow to be incorporated into North American medical schools.[46] At McGill University in 1876, William Osler, the great supporter of science and the use of instruments to sharpen physical diagnosis, was the first instructor in a Canadian medical school to offer a course based on

microscopic study. Using his own funds, Osler imported from Paris fifteen students' microscopes from the German instrument maker Edmund Hartnack.[47] With them he taught histology and clinicopathology (also known as the anatomo-pathological method, or the comparison of symptoms reported by the live patient with findings at autopsy). By 1900, many doctors bought their own microscopes and kept them in their home offices. By that date, the average microscope was relatively inexpensive and powerful, as it magnified up to 300 times and might be colour corrected.[48]

By the 1880s, enhancements in the microscope itself were matched by improvements in apparatus and procedures that allowed tissues, cells, and subcellular components to be viewed more easily.[49] These techniques and procedures were available to the keen clinician-researcher working in the home medical office, though they were time-consuming and required skill. Staining and other preparation of tissues was necessary to make the particles and details of a tissue sample visible or distinct for observation or counting. The first stains to provide contrast were natural ingredients such as saffron and carmine, but from the 1850s, artificial aniline dyes produced by the German textile industry were being used. By the early twentieth century, different types of tissue and bacteria were treated with specialized dyes and procedures with exotic names: Gram's stain for bacteria, methylene blue dye for fresh-frozen tissue biopsy, Romanovsky-type staining for blood smears, Oil Red O for lipids, and silver impregnation techniques for nerve cells. Tissue staining could require several steps and counterstaining, with washes and drying procedures.[50] The stained specimens had to be stabilized, or "fixed," by heating (in an oven or by open flame) or by chemical means (immersing in alcohol and ether, or with wood alcohol).

To make the best use of the microscope, the prepared specimen had to be very thin but of a constant thickness. After the tissue sample was made firm by embedding in a block of paraffin or celluloid, or by freezing, it was sectioned. A precision device called the microtome, introduced about 1830, had a blade aligned against the stage that held the specimen so that very thin uniform slices could be taken repeatedly. In 1885, Horace Darwin (the son of Charles) introduced an improved and enduringly popular automatic microtome known as the "Darwin rocker," produced by his company, Cambridge Scientific Instruments.[51]

The basic techniques of microscience — staining, fixing, embedding, sectioning, and mounting specimens on glass slides with cover slips for viewing — were taught in medical school and learned from journals. They are still used today and represent the contributions of hundreds of laboratory researchers, technicians, scientists, students, and doctors. Most of these innovations remain undocumented except where the inventor was or became a celebrated research scientist.

Microscopic Science and the Public Health Movement

Under their microscopes, late-nineteenth-century Canadian doctors and students saw living organisms in tissues and took part in a reinvigorated medical debate on the nature of disease. Antoni van Leeuwenhoek had sparked a controversy about the tiny creatures he detected with his simple microscope in the late seventeenth century: his successors argued for a century about whether or not particular organisms were benign.[52] Those who accepted that disease was caused by "animalcules" or other living organisms argued

Figure 2. *War metaphors and imagery pervaded public discourse on infectious disease, as in this 1927 cartoon, entitled "Water-borne Typhoid!". It celebrates the public health movement's success in controlling this acute bacterial illness, through preventative measures including water filtration and chlorination.*
(City of Toronto Archives, Public Health)

about whether the organisms developed as a result of spontaneous generation (out of a miasma) or through contagion (by direct transmission from one person to another).

The vastly improved nineteenth-century microscopes did not immediately end this debate. For example, though the famous surgeon Joseph Lister saw that body tissue swarmed with "microbes," he first believed that invisible and harmful organisms living in the air, not the body, were the cause of infections that commonly festered in the open wounds of his patients. However, in the 1860s and 1870s, Louis Pasteur and Robert Koch identified bacteria in water, milk, blood, and other bodily fluids. Using their microscopes and cultures, they confirmed that specific bacteria caused specific diseases. Beginning about 1880, the bacteriological explanation for disease became dominant, and by 1900, microbiologists had identified the tiny organisms responsible for many infectious diseases. The "microbe hunters," as they were coined by the following generation, contributed to the development of numerous tests, vaccines, antitoxins, and antibiotics. Ancient scourges including diphtheria, rabies, tetanus, tuberculosis, polio, and syphilis were eventually controlled, prevented, and cured.[53]

The control of infective agents through a variety of institutional and educational measures was the first target of social and environmental hygienists. Doctors who could see wiggling germs in water and milk, and thanks to bacteriological advances connected them to typhoid fever and other infectious illness in their patients, fought for infrastructure and regulation: municipal sewers, garbage disposal, water treatment, pasteurization of milk, and the sanitary inspection of dairies, butcher shops, farms, abattoirs, and restaurants. In Canada, Ontario passed the first provincial legislation to create a health board and department in 1883. (The federal government created its Department of Health in 1919.) Although public health structures, funding, voluntary and private associations, and projects differed across levels of government and by geographic region, certain themes and goals were common. Middle-class activists were most alarmed by the problems manifested in the lives of the urban poor. Inadequate housing, lack of sanitation and clean water, and the unhealthy habits of immigrants hurt the health of all city dwellers, they argued. The threat was both immediate, to contemporary Canadians, and long-term: poor health eroded the quality of the "germ plasm" (the genes) and risked the health of Canada's future generations.[54] The sanitary ideal — the battle against germs — was everywhere promoted through public education efforts. In the Maritimes, physicians focused on "sanitary science" in an effort to stamp out "dampness, darkness, and dirt" through a hygiene campaign in the public schools.[55] A slogan of the day informed people, "You don't catch Typhoid — you eat it or drink it."[56]

Public health laboratories were the urban command stations from which "microbe wars" were launched.[57] Although public health measures were undertaken in every province and have recently captured the interest of historians, the technology of public health laboratories has rarely been the focus of examination.[58]

Prevention of disease through the testing of milk, water, and food was an early and major goal of public health laboratories. Ontario's first bacteriological laboratory was established in Toronto in 1890 by the province. By 1910, other cities, including Hamilton, Ontario, and Vancouver, B.C., had municipal laboratories and full- or part-time paid city bacteriologists whose main tasks were to analyze water and milk for impurities. Milk carried not only typhoid but tuberculosis and diphtheria, doctors claimed. In Ontario, Adelaide Hoodless, the champion of home economics, and Charles Hastings, Toronto's medical officer of health, both campaigned for the pasteurization of milk after they lost children to contaminated milk. The introduction of sealed milk bottles ended the practice of customers buying milk by dipping their own (often unclean) containers into fly-ridden common tanks of milk.[59] In 1914, pasteurization was made compulsory for milk sold in Toronto.[60]

In the laboratory, relatively inexpensive technology and simple if painstaking technique were the only requirements for the testing of milk and water. A standard microscope, filters, plates, gelatin culture medium, and Petri dishes were the main apparatus required to identify contamination, especially infective agents.[61] Milk was tested for dirt by pouring it through a cotton filter, and for tuberculosis infection by examining it under the microscope. The centrifuge was another piece of equipment found in most laboratories. By turning its hand crank, the technician made its central chamber spin at high speed; the centrifugal force separated debris, pus, and other matter from milk and water. The centrifuge became less labour-intensive when electric models arrived in the 1930s; these machines quickly separated solid from liquid components of fluids, according to their different densities.

Toronto's public health laboratory may have been the best outfitted in Canada, with "separate room[s] for milk testing, sample preparation, serological, tuberculosis and diphtheria testing, and offices for the diagnostician and the clerical staff. On the wall of the laboratory, an 8′ by 6′ chart illustrated the various types of bacteria that workers were seeking as they conducted their tests."[62] The city's Health Department used technology not only for testing but also for teaching the public about the sanitary ideal and

bacteriological dangers. In 1913, the milk control staff took a model laboratory to the Canadian National Exhibition, and in 1918 the public were invited to a hotel to see clinical and bacteriological laboratory apparatus.[63]

Beyond prevention, controlling outbreaks of infectious disease was the second major responsibility of the public health laboratory, as can be illustrated with the example of diphtheria control in Toronto.[64] Diphtheria terrified parents and health workers; between 1880 and 1929, more than 36,000 Ontario children died of the disease, and outbreaks continued into the 1940s.[65] Doctors and advice manuals warned parents that this disease could strike quickly. The bacteria attacked the throat, tonsils, and nose, producing a leather-like membrane that could suffocate its victim.[66] Some ill-fated parents lost several children within hours to the disease. Diphtheria could also leave survivors permanently damaged.

For city dwellers, one of the public laboratory's functions was to identify cases for treatment by antitoxin. Diphtheria antitoxin, one of the first therapeutic triumphs of germ theory, was isolated from the blood of infected horses and used on sick children in Toronto in 1895. By the First World War, under the leadership of J. G. FitzGerald, it was manufactured by Toronto Public Health's Antitoxin Laboratories and used for treatment of the disease. However, children who lived in isolated communities rarely benefited, because the antitoxin was only effective if given in a large quantity within the first twenty-four hours of sickness. In Toronto (as in other North American cities), the Health Department instituted diphtheria "culture stations" in drugstores, where doctors could pick up throat swab kits and drop them off for delivery to the city lab, where the swabs would be tested by the next morning.[67] Antitoxin could then be administered to the positive cases, where, by one estimate in 1915, it cut the death rate from the disease from 16 percent to 6 percent.[68]

Another laboratory function was to sharpen isolation and quarantine strategies. Identifying diphtheria cases was important to prevent further spread of infection. Testing of throat cultures was the first

Figure 3. *From the 1890s, the City Laboratory was the epicentre of Toronto's aggressive public health campaigns against contagious diseases and impure water and milk. This 1912 photo was probably taken to document that the laboratory was an overcrowded and old-fashioned space.*

(City of Toronto Archives)

method whereby early or atypical diphtheria could be distinguished from other illness. After 1913, the control of diphtheria by quarantine improved with the Schick test. Diphtheria toxin, injected in small amounts under the skin, could indicate which individuals were immune to the disease (those whose skin did not respond with redness at the site). The test required care and skill to administer, a refrigerator in which to store the short-lived antitoxin, and the appropriate equipment of glass pipettes, rubber bulbs, and needles, and thus tended to be administered in a public laboratory rather than at a doctor's office. The Schick test identified not only susceptible individuals but also those with atypical symptoms and, perhaps most important, asymptomatic carriers who could transmit the disease without falling ill themselves. The Schick test was an example of the ways in which, in medical historian Peter Twohig's words, "the laboratory... would render the invisible menace visible."[69]

The first diphtheria immunization program started after 1913 when a toxin-antitoxin mixture was developed. In 1923, the French bacteriologist Gaston Ramon introduced an improved toxoid. Toronto physicians, though they were less opposed than British doctors, were still slow to adopt these measures, partly because they resented the Health Department's interference in what they considered to be private medical business.[70] Many hundreds of children died in Ontario cities before mass immunization was conducted with toxoids produced at the Connaught Laboratories. However, during the 1920s, because of the toxoid program, the death rate in Ontario from diphtheria began to decline, from almost 26 per 100,000 in 1920 to just over 6 per 100,000 in 1930.[71]

The history of public health initiatives shows that which projects were selected to receive official support depended on more than the availability of technology for identifying disease. As the threat from diphtheria waned, the attention of public health officials turned to the "secret plague," syphilis.[72] In 1905, the dark-field microscope had allowed researchers to identify the corkscrew-shaped organism that caused this sexually transmitted, highly contagious, and sometimes fatal disease. This in turn led to the development of the

Figure 4. *In contrast, Toronto's new City Laboratory, opened in 1912, shines with science. The camera focuses on the dedicated area for milk analysis with its own plumbing and lighting, the centrifuge, and the animal cages behind. Stainless steel equipment and fixtures have replaced wooden fittings, and the sole technician wears laboratory garb.*
(City of Toronto Archives)

Wassermann blood test in 1906. In this test, laboratory workers used the centrifuge to separate and remove red and white blood cells from the blood sample, leaving the clear serum. The Wassermann test was positive if antibodies to *Treponema pallidum* were detected. However, the Wassermann test did not become a priority of some Canadian public health departments until supplies of arsenical compounds to treat syphilis became assured (discussed in chapter 4). Thus, provincial laboratories such as Nova Scotia's Pathological Institute began Wassermann testing only in 1915.[73] In the 1920s, public health laboratories and hospital laboratories grew dramatically, through provincial and federal government funding earmarked for tests for syphilis.[74]

Despite the great successes that public health laboratories could justly claim, there were critics. Laboratory error rates were significant, pressure to work quickly was great, equipment was often substandard, specimens were contaminated with improper cleaning, and the quality of work varied from worker to worker. Many clinicians doubted the validity of the tests and claimed that the rate of false positives was high; some also resented the intrusion of public authorities into the private business of medicine. Among the Canadian public, too, there was ideological and pragmatic resistance to enforced reporting of disease as well as to compulsory isolation, quarantine, and vaccination.[75] In the case of influenza in 1918, for example, the lack of any reliable diagnostic test made quarantine measures ineffectual.[76] Yet the consequences of mandatory reporting and positive tests for infectious disease could be severe: children removed from their homes and exposed to infection in hospitals; dairies and butcher shops put out of business; in the case of syphilis, marriages and reputations possibly damaged beyond repair.[77]

New Clinical Tests and the Diagnostic Laboratory

New chemical and bacteriological tests were being developed and used with the microscope in laboratories to identify or confirm non-contagious as well as contagious disease. In areas serviced by public laboratories in the first decades of the century, doctors gradually abandoned their private laboratories as the required equipment grew more extensive and expensive and tests demanded more time and greater expertise.[78] The network of laboratories also expanded: public health laboratories became linked institutionally with hospital and academic laboratories, and sometimes operated out of the same physical space. For example, in 1915, the Ontario government outfitted the Institute of Public Health, at the University of Western Ontario, with well-equipped laboratories to train medical school graduates and nursing students, to do bacteriological and other testing for farms and boards of health, and to conduct research.[79]

Individual practitioners could send samples for analysis to public laboratories from the early 1890s. In 1895, young Dr. W. T. Connell (1873–1964), the chair of the Department of Pathology at Queen's University in Kingston, offered " 'a wide variety of analyses for the practicing physicians in Eastern Ontario' (including chemical testing)" from his laboratory.[80] There were also clinical pathology laboratories in Toronto (at the University of Toronto Medical School) and Montreal (the Royal Victoria Hospital).[81] As Stanley Reiser notes, "Laboratory development during the nineteenth century can be thought of as a chain of links that began with the laboratory devoted to basic research; was followed by the clinical laboratory, which split its efforts between research and patient care; and ended with the ward laboratory, the workshop next to the patient, where the knowledge and methods perfected in the other laboratories were most practically applied."[82]

At the beginning of the century, urine was the most tested bodily fluid. Urinalysis has an ancient history in the art of uroscopy, whose medieval practitioners claimed to divine health from the smell, taste, and colours of urine.[83] By the late nineteenth century, simple (if not infallible) tests on the composition of urine could be done without the microscope or specialized instruments, and therefore could be conducted in hospital wards by nurses rather than in specialized laboratories.[84] Clinicians could measure the specific gravity of urine (the concentration of particles in it) to test for diabetes as well as renal and heart failure, without any technology more complicated than a heat source. The glass ureometer (for gauging how the kidneys were filtering out the waste product, urea, in the blood or urine) and the albuminometer (a glass tube that facilitated the heating of urine to test for the white precipitate that indicated albumin) were available by mail order and simplified the work.

Chemical tests included the nitric acid test that identified albumin, a protein that indicated kidney disease; Fehling's glycerine test for the presence of glucose, to indicate diabetes; and a test for bilirubin, the bile pigment that often indicates blocked bile ducts. By 1900, urinalysis kits that included apparatus for a number of these tests, such as those sold by George Tiemann of New York, were advertised in the medical journals that Canadian doctors read. Most of these visual and chemical tests produced qualitative rather than quantitative results: for instance, the substance being tested for was either present or absent.[85] As microscopes offered greater magnification and the knowledge accumulated from hundreds of clinical researchers,

urinalysis was able to break down clusters of symptoms, such as the condition called Bright's disease, into more precise diagnoses.

The microscope became more powerful clinically — that is, able to provide data for differential diagnosis — with the development of blood tests and counting technology, but these innovations made the tests less suitable for the doctor's office and more likely to be conducted in the clinical laboratory. The first counting chambers were glass slides with precision-made grids marked in metric units (because the leading scientific instrument manufacturers were European), for use under a microscope. The results of a count could then be compared to rapidly accumulating charts of standards, and diagnosis would be assisted. Red blood cell counts helped to identify kidney and heart disease and various anemias. The hemocytometer and the hemoglobinometer were instruments used to count levels or concentrations of specific blood substances (red corpuscles and hemoglobin, respectively.)[86] From the 1880s, the centrifuge made counting red blood cells faster, less tedious, and more accurate; its "whirling motion forced the [red blood] cells to the bottoms of the tubes where, as a compact mass, their volume could be measured and the number of cells calculated."[87] White blood cells began to be counted in 1892 after researchers learned that an increased number of leucocytes indicated infection, allergy, and other conditions.

By 1900, a range of body fluids, including sputum, gastric washings, and cerebrospinal fluid, were being tested, and various tissues were being examined under the microscope for the presence of cancer, for example. The introduction of the hypodermic needle with syringe had made obtaining human blood samples for testing easier. (Blood-letting had fallen out of favour as a therapy, thereby reducing testing opportunities.)[88] However, large volumes of blood were still required for each test. Refinements in needles and more accurate chemical analysis at the turn of the century reduced the amount of blood required and made blood removal for non-therapeutic purposes, such as the monitoring of blood sugar, more acceptable to the patient.[89]

Although this period saw the rapid expansion of laboratory testing, doctors and patients were under no illusions that laboratory technology could deliver a cure for most ailments. Despite the multiplication of tests and the marvels of precision instruments, the volume of knowledge from scientific investigation far exceeded its practical utility, well into the twentieth century. As a result, even in hospitals, urinalysis and other specialized tests as well as X-ray machines were used only infrequently until the 1920s.[90] Doctors warned that some diagnostic procedures were unreliable and unsafe for patients. Medicine was still an art, they argued, and the truth of most diagnoses could be confirmed only after death, on the autopsy table. As stated by Joel Howell, "[American] physicians rarely used laboratory tests to guide their clinical decisions; patients rarely thought that science could be relevant for their day-to-day care."[91] The failure of technology to point the way to a cure or to greater relief of symptoms explains, in part, why clinicians more than medical academics reacted with skepticism or hostility to positive claims made for laboratory science and technology.[92]

Historians have added their critical opinions to the voices of contemporaries as a corrective to reductionist views that celebrate the rise of technology and science. They have demonstrated that the microscope helped to change the way doctors classified disease, and that this nosological change increased the therapeutic pessimism of the early twentieth century. As explained by Audrey Davis, the pathological-anatomical method encouraged clinicians to separate diseases according to prognosis. Functional diseases were those that were possibly responsive to treatment or would pass with time — they left no permanent imprint on the anatomy. Organic or structural conditions presented a darker picture: the lesion of tissue deterioration or structural abnormality was permanent, the prognosis often fatal. When the microscope revealed organic disease, doctors predicted a gloomy outcome regardless of the symptoms of the patient.[93] William Osler, whose studies in pathology gave him an intimate knowledge of the deterioration of the aging body, wrote and spoke of "the uselessness of men above sixty years of age," and included himself in his harsh judgment.[94]

Instruments, Laboratories, and the Structure of the Health Professions

The weight of technology — apparatus, practices, and knowledge — shifted the balance of power within and among traditional occupations in medicine and health, but the pattern is complex. In the laboratory, occupational categories were fluid, for different kinds of workers were responsible at different periods for technology that itself was changing across the decades. Laboratory labour is receiving attention from historians, but as in most Canadian health history, there is much left to be studied. As in the case of X-ray departments, the operation of machines, the administration of tests, the sterilization of glassware and equipment, and sometimes even the management of departments were functions originally relegated to nurses or other lower-status workers, while the intellectual action of diagnosis was reserved, in theory at least, for doctors.[95] In this period, of course, most doctors were male. In the Maritimes, hospital and public health laboratory technicians were usually women, paid at less than living wages, invisible to their contemporaries and to

most historians. However, in Dalhousie University's medical science laboratories, whose focus was education, and in Toronto's public health laboratories, as Figure 3 suggests, the workers were men.[96] Regional variation seems, therefore, to have influenced the class and gender of who operated and controlled the technology.

The practice and technology of medicine influenced developments within the medical profession as well as between occupational groups. General practice declined in status as the tools and techniques of the laboratory and the hospital multiplied in number and became too complex or expensive for the doctor's office. Country doctors (and patients) had restricted access to costly instruments and laboratories as technology pushed the clinical branch of medicine farther away from research. The new elite, as clinical medicine declined in status, were the academic researchers. Physiology encouraged the first full-time faculty researchers and the "research ethic" — the conviction that medical teachers had the duty to build medical knowledge through research for the good of society.[97] Surgery also rose in status from about 1890, mostly because surgeons could perform spectacular and sometimes life-saving feats. But laboratory technology, especially blood analysis, also allowed surgeons to carve out a larger practice: they could do diagnosis with the microscope and be "independent of the clinical observations of their physician colleagues."[98]

Particular specialties formed around powerful tools like the ophthalmoscope (ophthalmology) and the X-ray (radiology), both at first office-based practices, though the latter became a hospital-based specialty in the 1920s. The new specialists developed their own languages and routines that excluded the generalists. The ophthalmoscope, invented in 1851 by the German physician-scientist Hermann von Helmholtz, gave doctors easy entry to the mysteries of the body through the eye. Partly because it allowed its operator to treat as well as diagnose, the ophthalmoscope was the most powerful of the early viewing devices. With this tool, surgeons were able not only to see the interior of the eye, but also to operate on the iris and correct strabismus (cross-eye or deviating eye). With the help of the

Figure 5. *Dr J. Nisbet Gunn examines a patient in his office in Calgary, circa 1910. The ophthalmoscope, light sources, and other technology shown here allowed Gunn to become one of the first ear, eye, nose, and throat specialists in Western Canada.* (Glenbow Archives, NA-4002-27)

Toronto optician Charles Potter, A. M. Rosebrugh developed his own photographic ophthalmoscope — it recorded views of the fundus of the eye — and became Canada's first specialist in the field in the 1860s.[99] Because the eye could reveal signs of disease beyond eye disease, such as heart and kidney disorders, the scope allowed ophthalmologists to claim superior diagnostic abilities and to fashion a large field for themselves out of general practice.

As specialization developed, those who based their authority on anatomical rather than physiological knowledge ("old"-style cardiologists) or who did not routinely use instruments of measurement in their practice (obstetricians, asylum doctors) appeared old-fashioned.[100] Traditional pathologists who specialized in post-mortem examination lost status as laboratory-based science, especially hematology, claimed the ability to diagnosis disease before the post-mortem, and in so doing help the living patient.[101]

Alliances of medicine and industry have produced subspecialties with signature technology and procedures with influence beyond their sector. An early example of occupational medicine appeared in the railway industry. The trauma that train accidents inflicted on employees and passengers brought into being a professional association of railway surgeons whose membership included Canadian doctors. It also stimulated the development of first aid. Charles Dickson, a Canadian member of the St John Ambulance Association, wrote an influential first aid manual for North American railway surgeons and taught courses to Canadian Pacific employees.[102] The railway industry was also the first to apply scientific management principles and pioneered specific medical measurements of ability and disability.[103] Railway surgeons used specialized tools to assess the abilities of employees and potential employees. In Canada, from about 1889, hiring policies of railways required that engineers and firemen pass tests that detected colour-blindness and other problems in vision, despite contemporary criticism that this requirement did not measure the multiple visual abilities that were the most important.[104] Vision tests used simple equipment such as charts and coloured strings.

Other industries developed apparatus to test fitness for work as well as for damage allegedly caused on the job. For instance, factory doctors used the aesthesiometer to gauge the sensitivity to stimuli of individuals who claimed they had suffered paralysis or neurological damage as a result of accidents or electric shocks. Acoustical equipment such as the tuning fork and whistle, the best models made by Rudolph Koenig of Paris, were used to test for work-related or hysterical deafness. There was also an olfactometer to use where the sense of smell was impaired. The dynamometer gauged muscle strength of applicants to police and fire departments. It was the basis of the "Test your strength!" machines common in fairgrounds across North America.

By the 1920s, both within and outside of the profession, there was a growing belief that the future of medicine lay in science, not art. The demand for medicine with at least the veneer of science was expanding in both medical and lay circles. Middle-class patients and outpatients of the new hospitals demanded the latest and the best, or at least the chance at restored health that new technology might provide. As laboratory tests, machines, and devices became more reliable or at minimum more familiar, even clinicians were reconciled to their use and attracted by some of the benefits they offered. For example, the sphygmograph, or pulse writer, measured the rate of the pulse, something that a doctor with a watch could do with his hand, but only a machine could provide a permanent record of the results in a tracing on a graph. The physician could therefore track changes in an individual patient and measure the effect of drug therapy.[105] As William Osler commented, not without sadness, "We clinicians must go to the physiologists, the pathologists and the chemists — they no longer come to us."[106]

Conclusion

This brief survey of medical technology in Canadian practice and research in the first decades of the twentieth century underscores that modern medical technology was born of nineteenth-century science — first pathology and anatomy, then physiology, and later bacteriology and biochemistry. It also confirms that "the laboratory was a key feature of medical education, the location of medical authority, and the site of medicine's most prominent discoveries, including the tubercle bacillus, diphtheria antitoxin, and others."[107] Microscopic confirmation that bacteria caused much disease, combined with ineffective therapeutics, encouraged physicians and scientists to look beyond individual patients to whole populations. The rise of public health was one positive consequence.

Notwithstanding the compulsory measures and inequalities of its history, the Canadian public health movement saved and improved millions of lives. Toronto's public health department, a leader in the development of public health education, nursing, and milk safety, was the model for North American cities.[108] In the control of sexually transmitted diseases, "the marriage of German science to Canadian public health philosophy" led to world leadership in the control of syphilis and other sexually transmitted diseases.[109] At the same time, as Georgina Feldberg argues, because Canada's colonial history disposed its physicians to follow British example without a national

agenda (unlike the Americans), Canada's "public health apparatus . . . served increasingly as a testing site for foreign biomedical theories and technologies."[110]

In clinical practice, instruments and apparatus — the thermometer, the stethoscope, the microscope, and other equipment for fluid and tissue tests — were mainly directed at diagnostics rather than therapeutics. In the nineteenth century, instruments were considered to be extensions of the doctor's five senses, to enhance the diagnosis obtained by physical means. They provided qualitative data whose utility depended upon the skills, experience, and knowledge of the user. By the early twentieth century, as the principles of science infused medicine, medical technology was destined in part to supplant the art of diagnosis, by producing objective, standardized, and communicable results (though technology did not always meet expectations). This change in the use of instruments in turn modified the doctor-patient relationship and transformed the profession of medicine, by promoting specialization. The trajectory of innovation moved away from the clinician-scientist and the consulting office to the university and hospital laboratory,

By 1920, it was apparent to Canadian doctors and observers that medicine was winning battles in the war against infectious disease. Medical technology held out great possibilities for the relief of many illnesses, diseases, and conditions. But it was also obvious that technology could impose a price of frustration and risk for doctors and patients. In the world beyond medicine, the advent of health standards and the analysis of vital statistics underlined that medicine still could do little more than categorize the problems for most of the sick and disadvantaged in Canada.

Notes

1. Jacques Bernier, *Disease, Medicine and Society in Canada: A Historical Overview* (Ottawa: Canadian Historical Association, 2003), 13.
2. "Age-Standardized Mortality Rates," *Canadian Statistics*, Statistics Canada, www.statcan.ca/english/Pgdb/health30a.htm (accessed January 15, 2004).
3. Infectious diseases are caused by pathogens or biological agents; contagious, also known as communicable, diseases are spread by bodily contact from person to person. Infectious diseases are not necessarily contagious.
4. Esyllt W. Jones, " 'Co-operation in All Human Endeavour': Quarantine and Immigrant Disease Vectors in the 1918–1919 Influenza Pandemic in Winnipeg," *CBMH* 22, no. 1 (2005): 59–60; Valerie Minnett and Mary-Anne Poutanen, "Swatting Flies for Health: Children and Tuberculosis in Early Twentieth-Century Montreal," *Urban History Review* 36, no. 1 (October 2007): 34.
5. For the transformation of the hospital, see Charles E. Rosenberg, *The Care of Strangers: The Rise of America's Hospital System* (New York: Basic Books, 1987); J. T. H. Connor, *Doing Good: The Life of Toronto's General Hospital* (Toronto: University of Toronto Press, 2000).
6. Jacalyn Duffin, *Langstaff: A Nineteenth-Century Medical Life* (Toronto: University of Toronto Press, 1993), 161–4.
7. Julian Smith, *William R. Beaumont: Mechanical Genius* (Markham, Ont.: Fitzhenry & Whiteside, 1995). For U.S. surgical instrumentation, see James M. Edmonson, *American Surgical Instruments: An Illustrated History of Their Manufacture and a Directory of Instrument Makers to 1900* (San Francisco: Norman Publishing, 1997).
8. Sir John A. Macdonald received a hypodermic for relief of the pain of a kidney stone in 1874. James Grant, "Incidents in the Life of a Physician," *CMAJ* 6, no. 4 (April 1916): 302.
9. J. T. H. Connor, "Medical Technology in Victorian Canada," *CBMH* 3, no. 1 (1986): 97–123, on which the following section relies. For more on electrotherapeutics, see J. T. H. Connor and Felicity Pope, "A Shocking Business: The Technology and Practice of Electrotherapeutics in Canada, 1840s to 1940s," *Material History Review* 49 (1999): 60–70; Christine E. Graham, "Twenty Years' Growth in Physiotherapy," *CMAJ* 43, no. 4 (October 1940): 380–1.
10. Audrey B. Davis, *Medicine and Its Technology: An Introduction to the History of Medical Instrumentation* (Westport, Conn.: Greenwood Press, 1981), 142.
11. F. Adams, trans., "On the Surgery," in *The Genuine Works of Hippocrates*, vol. 2, 474 (London: Sydenham Society, 1849), cited in Malcolm Nicolson, "The Art of Diagnosis," in *Companion Encyclopedia of the History of Medicine*, vol. 2, ed. W. F. Bynum and Roy Porter (London: Routledge, 1993), 802. On physical diagnosis, see W. F. Bynum and Roy Porter, eds., *Medicine and the Five Senses* (Cambridge: Cambridge University Press, 1993).
12. Robert Bennett Bean, coll., and William Bennett Bean, ed., *Sir William Osler: Aphorisms from His Bedside Teachings and Writings* (Springfield, Ill.: Charles C. Thomas, 1961), 103.
13. Michael Bliss, *William Osler: A Life in Medicine* (Toronto: University of Toronto Press, 1999), 266.
14. Jacalyn Duffin, *To See with a Better Eye: A Life of R. T. H. Laennec* (Princeton: Princeton University Press, 1998), 129–30.
15. Jens Lachmund, "Making Sense of Sound: Auscultation and Lung Sound Codification in Nineteenth-Century French and German Medicine," *Science, Technology & Human Values* 24, no. 4 (August 1999): 424.
16. Stanley J. Reiser, *Medicine and the Reign of Technology* (New York: Cambridge University Press, 1978), 43. However, Duffin holds that Laennec valued physiology as well as anatomy as the twin bases of diagnosis; *To See with a Better Eye*, 236–9, 286–7.
17. For the history of clinical pathology, see Roy Porter, *The Greatest Benefit to Mankind: A Medical History of Humanity* (New York: W. W. Norton & Co., 1997), 306–8; E. H. Ackerknecht, *Medicine at the Paris Hospital, 1794–1848* (Baltimore: Johns Hopkins University Press, 1967); W. F. Bynum, *Science and the Practice of Medicine in the Nineteenth Century* (New York: Cambridge University Press, 1994); Russell Maulitz, *Morbid Appearances: The Anatomy of Pathology in the Early Nineteenth Century* (Cambridge: Cambridge University Press, 1987).

18. Harold N. Segall, "Introduction of the Stethoscope and Clinical Auscultation in Canada," *Journal of the History of Medicine and Allied Sciences* 22 (1967): 414–7. Francophones may have been faster to adopt the stethoscope; see Joseph Hanaway, Richard Cruess, and James Darragh, *McGill Medicine*, vol. 2, *1885–1936* (Montreal: McGill–Queen's University Press, 2006), 12.
19. Joseph Workman, the most famous nineteenth-century psychiatrist in Canada, ordered almost four hundred post mortems in his years as head of the Toronto Asylum. Alfred E. Lavell, ed., *Extracts from the Diary of Joseph Workman*, vol. 1, *1867–82*, entry for September 23, 1880. See also John H. Arton, "Insanity and its Medico-legal Aspects," *The Canada Lancet* 18, no. 5 (January 1886): 127–130.
20. This paragraph relies on Davis, *Medicine and Its Technology*, 87–115; Reiser, *Medicine and the Reign of Technology*, 23–44.
21. For illustrations and detailed development, see M. Donald Blaufox, *An Ear to the Chest: An Illustrated History of the Evolution of the Stethoscope* (London: Parthenon, 2002).
22. Lachmund, "Making Sense of Sound," 419–50.
23. For more on the McGill Museum of Medicine, see Hanaway, Cruess, and Darragh, *McGill Medicine*, vol. 2, 13–5.
24. Merriley Borell, "Training the Senses, Training the Mind," in *Medicine and the Five Senses*, ed. W. F. Bynum and Roy Porter (Cambridge: Cambridge University Press, 1993), 251–4.
25. Duffin, *Langstaff*, 64–5.
26. Porter, *Greatest Benefit to Mankind*, 311.
27. William Coleman and Frederic L. Holmes, eds., *The Investigation Enterprise: Experimental Physiology in Nineteenth-Century Medicine* (Berkeley: University of California Press, 1988). See also Gerald L. Geison, ed., *Physiology in the American Context, 1850–1940* (Bethesda, Md.: American Physiological Society, 1987).
28. Porter, *Greatest Benefit to Mankind*, 265.
29. Merriley Borell, "Instrumentation and the Rise of Modern Physiology," *Science & Technology Studies* 5, no. 2, annual meeting issue (Summer 1987): 55, on which this paragraph relies.
30. A phrase used by Oliver Wendell Holmes in 1884, in "The Address Delivered in Huntington Hall," cited in Henry P. Bowditch, "The Prototypical Full-Time Physiologist and Educational Reformer," in *The Development of American Physiology: Scientific Medicine in the Nineteenth Century*, by W. Bruce Fye (Baltimore: Johns Hopkins University Press, 1987), 125.
31. For a comprehensive study of the history of the medical thermometer, see Davis, *Medicine and Its Technology*, 61–85.
32. Porter, *Greatest Benefit to Mankind*, 345.
33. Duffin, *Langstaff*, 68.
34. Recent scholarship on the history of scientific instruments suggests there was a more extensive American trade than originally thought. See, for example, Edmonson, *American Surgical Instruments*, and David Pantalony, Richard L. Kremer, and Francis J. Manasek, *Study, Measure, Experiment: Stories of Scientific Instruments at Dartmouth College* (Dartmouth, N.H.: Terra Nova, 2005). Thank you to David Pantalony for drawing our attention to this.
35. R. Benschop and D. Draaisma, "In Pursuit of Precision: The Calibration of Minds and Machines in Late Nineteenth-Century Psychology," *Annals of Science* 57, no. 1 (January 2000): 1–25.
36. Douglas J. Lanska, "The Role of Technology in Neurologic Specialization in America," *Neurology* 48 (1997): 1724.
37. Davis, *Medicine and Its Technology*, 83.
38. Alberta Hanscome, *History of the Saint John General Hospital and School of Nursing* (Saint John, N.B.: Lingley, 1955), appendix, n.p. Montreal General Hospital Surgical Ward had clinical wall charts by 1892, Hanaway, Cruess, and Darragh, *McGill Medicine*, vol. 2, fig. 13.
39. Stanley J. Reiser, "The Technologies of Time Measurement: Implications at the Bedside and the Bench," *Annals of Internal Medicine* 132, no. 1 (January 2000): 31–6.
40. Davis, *Medicine and Its Technology*, 159.
41. Among many sources, see Gerard L'Estrange Turner, *The Great Age of the Microscope: The Collection of the Royal Microscopical Society through 150 Years* (New York: Hilger, 1989); Brian Ford, *Single Lens: The Story of the Simple Microscope* (London: Heinemann, 1985); Gerard L'Estrange Turner, *Essays on the History of the Microscope* (Oxford: Senecio, 1980); Savile Bradbury, *The Evolution of the Microscope* (Oxford: Pergamon Press, 1967); Donald L. Padgitt, *A Short History of Early American Microscopes* (Chicago: Microscope Publications, 1975); Nicolas Rasmussen, *Picture Control: The Electron Microscope and the Transformation of Biology in America, 1940–1960* (Stanford, Conn.: Stanford University Press, 1997).
42. Porter, *Greatest Benefit to Mankind*, 223–6, for the early history of the microscope.
43. Jacalyn Duffin, *History of Medicine: A Scandalously Short Introduction* (Toronto: University of Toronto Press, 1999), 181.
44. Connor, "Medical Technology in Victorian Canada," 101–2.
45. Harry Letts and John Jacques, "Under the Microscope: The Evolution of Pathology and Laboratory Medicine in Canada," Canadian Association of Pathologists Web site, http://cap.medical.org/history_pathology_laboratory-med.htm (accessed September 19, 2007), 10. On Virchow, see Ian F. McNeely, *"Medicine on a Grand Scale": Rudolf Virchow, Liberalism, and the Public Health* (London: Wellcome Trust, 2002).
46. Hanaway, Cruess, and Darragh, *McGill Medicine*, vol. 2, 50.
47. Joseph Hanaway and Richard Cruess, *McGill Medicine*, vol. 1, *The First Half-Century, 1829–1885* (Montreal: McGill–Queen's University Press, 1996), 69–71.
48. In the 1930s, the first electron microscope brought magnification of 20,000 times and greatly improved resolution, as discussed below, but the vacuum in which samples were placed killed living material. The latter was not visible until the 1950s and the development of the phase-contrast light microscope. See Brian Bracegirdle, "The Microscopical Tradition," in *Companion Encyclopedia of the History of Medicine*, vol. 2, ed. W. Bynum and R. Porter (London: Routledge, 1993), 115; Davis, *Medicine and Its Technology*, 146.
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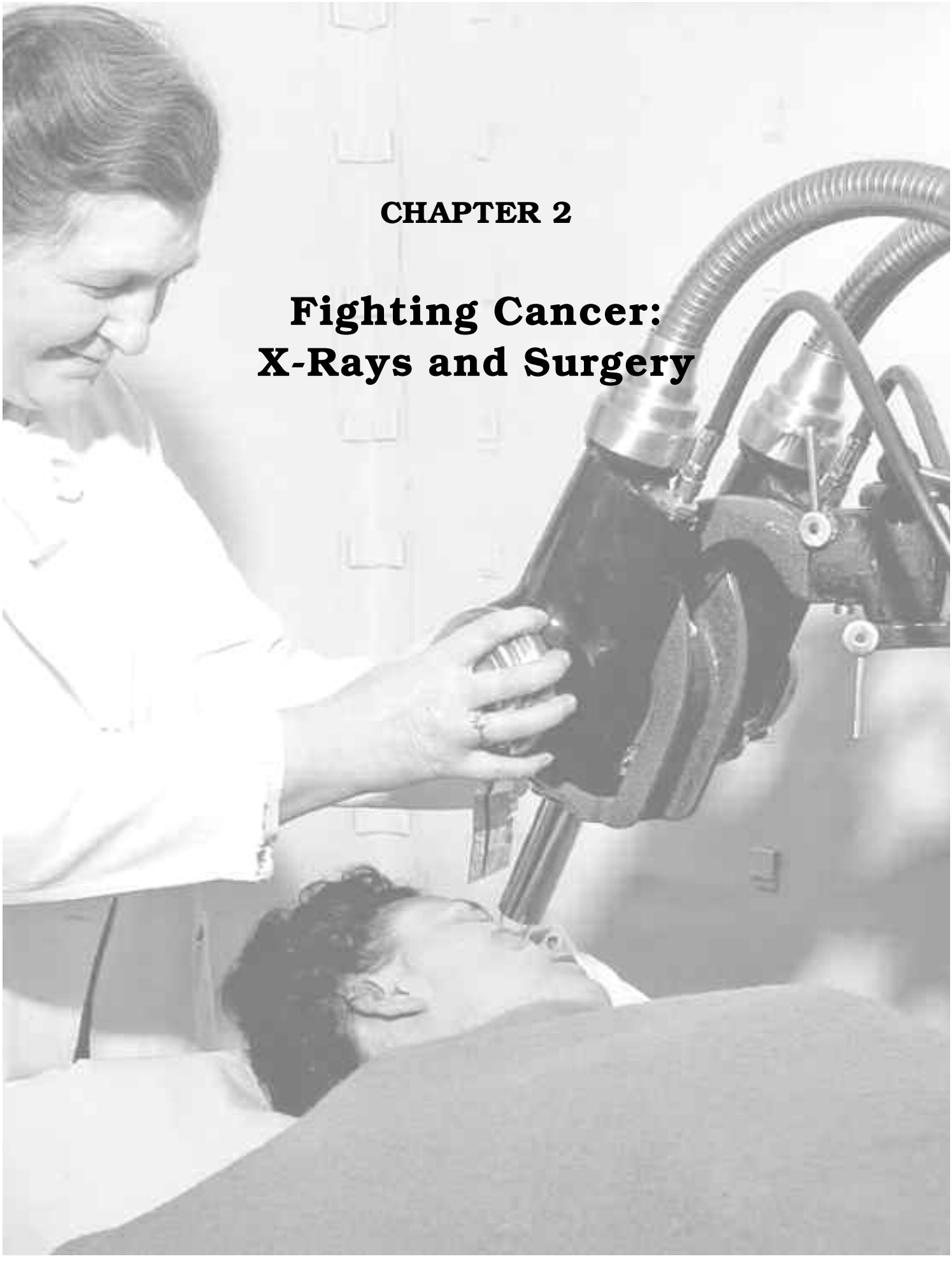

CHAPTER 2

Fighting Cancer: X-Rays and Surgery

Fighting Cancer: X-Rays and Surgery

From 1896, X-rays and associated technology allowed doctors to visualize and to treat the body in ways never before possible. The newly discovered invisible rays could not only perform diagnostic miracles, but they also offered therapeutic possibilities for stubborn and dangerous conditions. These two functions — the diagnostic and the therapeutic — led the development of X-ray technology in two different directions. This chapter explores the history of radiation technology as a diagnostic and therapeutic weapon in the fight against cancer, a rising killer of the twentieth century. Although the chapter's focus is on ray technology, competing and complementary technologies will also be described. Surgery emerged as both a therapeutic and a diagnostic procedure, and grew in response to the limitations and successes of ray technology. Developments in vaccines and drugs also shaped the use of radiation therapy.

Europeans invented ray technology, but Canadians participated enthusiastically in its development. Canadian engineers, scientists, and doctors added important innovations in fluoroscopy and in surgery, the competing and complementary technology.

The Adoption of X-Ray Technology in Canada

> *Prof. Roentgen's wonderful photographic process has been repeated in the Macdonald Physics building, Prof. Cox having obtained a photograph of a student's hand, as follows: — A Stanley dry plate (sensitomer No. 50) was placed in an ordinary mahogany plateholder, which was kept closed during the exposure, the hand was placed up on the outside of the plate-holder and the rays from a Crookes tube allowed to fall upon the whole for about five minutes. Upon developing in the ordinary way a negative silhouette of the hand was obtained.*[1]

As this early 1896 *Toronto Globe and Mail* article conveys, the Canadian public and medical profession responded with great interest and excitement to the first X-ray "silhouettes," and to the possibility of seeing inside the living body. The explanation of the phenomenon was also circulated. X-rays "work" by registering the passage of rays through tissue. The rays are absorbed or scattered in a predictable way according to the type of body tissue. Soft tissues — skin, muscle, and organs — do not absorb X-ray photons, while hard tissues — such as bones — absorb these electromagnetic particles. As the X-ray beam is attenuated or reduced in intensity according to the material it passes through, a chemical reaction causes a negative image to register on light-sensitive media.[2]

Stimulated by the diagnostic possibilities as were doctors in other countries, Canadian physicians published sixty articles on the use of the X-ray in the twenty-five years after its introduction. The most prolific, Dr James Third of Kingston, wrote on the ability of the X-ray to locate in the abdomen foreign objects (such as bullets and swallowed needles), to identify calculi (kidney stones, gallstones, etc.) and to diagnose fractures.[3] The McGill University professor John Cox has received credit for the first clinical X-ray taken in Canada, in February 1896. The X-ray located a bullet in a patient's leg, and the film was later used as evidence in court, probably the first forensic use of radiography.[4]

The proliferation of knowledge from X-rays was possible because the first machines were based on simple technology. Within a month of the physicist William Roentgen's accidental discovery of this new type of ray in late 1895, an entrepreneur with a hand fluoroscope had been working on Yonge Street in Toronto, selling to amazed passers-by the chance to view the interior of their hands for a quarter.[5] Roentgen himself promoted his invention through scientific publications, medical journals, and popular literature, and he refused to patent it, in accordance with altruistic scientific ethics of the day. Scientifically minded Canadians quickly developed their own apparatus. In university physics and engineering departments, academics made their own machines because what was needed to create the new rays was readily at hand — an induction coil to supply the power and a Crookes tube through which to pass the electrical current could be found in most physics laboratories.[6]

Alexander Graham Bell, the well-known Canadian scientist and inventor of the telephone, was also excited by Roentgen's discoveries. In 1896, Bell ordered a Crookes tube from a Philadelphia manufacturer, took a number of radiographs (X-ray pictures), then wrote about the possibilities for a "stereo radiograph," which, like the old-fashioned stereoscope or the modern CT scan, could generate three-dimensional images.[7] He was also the first person to try to transmit

X-ray signals over the telephone, a technology that developed into what is known today as teleradiology.[8]

In the United States and Europe, a number of manufacturers of scientific equipment rapidly entered the X-ray market because barriers to entry were at first low.[9] Within a few years, however, several equipment manufacturers in the United States controlled the design and production of ever larger and more complicated ray technology for the North American market.[10] According to the limited literature on early medical technology developed or manufactured in Canada, there were only a few Victorian domestic medical instrument makers. The historian J. T. H. Connor has identified about thirty devices or modifications introduced by doctors, scientists, and other enterprising individuals, with and without patents. Generally modifications of existing technology, most of them did not travel beyond their inventors.[11] The Canadian market was small; it is not surprising, therefore, that the first X-ray machine for hospital use was imported from the United States and may have gone to the Kingston General Hospital, in 1896, largely due to Dr Third's promotion of the technology.[12]

Hospitals were the logical site to house the second generation of X-ray machines. The Toronto General Hospital already had a number of electrotherapeutic devices, including galvanic batteries and cauterizing equipment, and it acquired X-ray apparatus in late 1896.[13] In 1900, Toronto's Hospital for Sick Children acquired a fluoroscope, then an X-ray machine that was donated by the Edison Company, one of the largest equipment manufacturers in North America at the time. The Saint John Hospital got its first X-ray machine in 1897[14] and Halifax's Victoria General in 1903,[15] but the records of the large Royal Victoria Hospital in Montreal indicate that it had no X-ray equipment until it purchased the "Snook" machine in 1908.[16] Moncton's X-ray equipment arrived in 1912, and the Owen Sound General and Marine Hospital bought theirs in 1918.[17]

Figure 6. *Early "radiographers" — photographers, nurses, and physicians — did not fully understand the dangers of radiation exposure. As an X-ray is taken at Colonel Belcher Hospital in Calgary in the late 1920s, both patient and technician are wearing street clothes; no protective gear is in evidence.*
(Glenbow Archives, NA-2901-10)

Historians are interested in local and regional variations in timing between the invention and uptake of X-ray technology. Sometimes a single event rather than the cultural and medical context changes the course of technology uptake. In Halifax, Victoria Hospital maintained a modest X-ray department from 1903. However, in 1917, during the First World War, the explosion of the munitions ship the *Mont Blanc* left 1,600 dead and many thousands wounded, placing overwhelming demands on the city's medical facilities and personnel. The American Red Cross provided a modern X-ray machine and operators for the crisis. In the aftermath, convinced of the value of the technology, Victoria Hospital administrators began to upgrade their X-ray department.[18] In Canada, as elsewhere, institutional responses to new technology also reflect regional medical and cultural differences. In Quebec, the adoption of X-ray technology had an ethnic variable. According to Yves Gingras, the first Canadian experiments with the rays were in the Physics Department at the English-speaking McGill University. In contrast, the francophone universities in the province were not interested in knowledge production but in teaching, or transmission, of the knowledge.[19]

Uptake was also related to local doctors' degree of interest in and financial commitment to the new technology. Until the 1920s, patients who wanted X-rays were more likely to receive them at a doctor-enthusiast's office than at a hospital, and physicians interested in various types of electrotherapy seem to have been the first to incorporate the X-ray machines into their arsenal.[20] As X-ray apparatus grew more complex and expensive, doctors looked to hospitals to share the capital and operating costs. It was typical for hospitals to set up early X-ray apparatus only after they had arranged a cost- and profit-sharing venture with a local doctor, a sometimes controversial funding strategy, as in Sydney, Nova Scotia, in 1928.[21] The historian Joel Howell argues that regional differences in the development of supporting technology, particularly the availability of electricity as a light source, determined whether the X-ray machine would be a profit-making venture for hospitals.[22] X-ray departments could be very profitable; the Moncton Hospital was charging up to $25 per stomach X-ray in 1920.[23]

The early history of X-ray technology illustrates that technology was central to the rise of specialization and the hospital. At the same time, it challenges the usual conception of health and hospital professionals as having discrete occupational categories from their early formation.[24] Photographers and others with technical skills, not physicians, were often the first operators, inside and outside the hospital.[25] In Toronto, the "virtual founder of the discipline of radiology" in Toronto, Percy Ghent, was an orderly.[26] In Halifax, Charles Puttner, once the hospital purchasing agent and apothecary, took charge of the electrotherapeutic department in 1904.[27] Peter Twohig has also shown that, as in hospital laboratories, the management and staffing of X-ray departments changed over time.[28] In the first decades of the twentieth century, physiotherapists moved between their hydrotherapy equipment and actinotherapy machines (radiation therapy for cancer).[29] Nurses commonly managed the X-ray department and conducted the radiological examinations.[30] At St Michael's Hospital in Toronto, nursing religious Sisters Carmela and Felicitas were among the women who managed the first X-ray machines before 1918.[31] At St Paul's Hospital in Vancouver, the ingenious and thrifty Sister Charles not only ran the X-ray department but "created an X-ray identity machine out of a packing case, a treadle from an old sewing machine, and an electric light bulb."[32]

By the late 1920s, however, medical doctors, now called radiologists, were in charge of ray technology in the hospitals. This development was partly in response to the requirements of the accreditation system established in 1918 by the American College of Surgeons.[33] Even small hospitals were actively acquiring the newest technology, to gain accreditation, and to attract physicians and paying patients. Hospitals were the proud homes of the latest scientific technology, particularly in the diagnostic laboratories and the X-ray departments; beside them, the doctor's office and the bedside seemed old-fashioned and inadequate places to determine what was wrong with the modern patient. Clinicians who had doubted the efficacy of the technology and who perhaps feared that these machines made their hard-earned diagnostic skills redundant were eventually won over as paying patients made it clear that what they wanted was the latest in medical devices.[34] Accordingly, interpreting the data from X-ray machines became exclusively medical responsibilities and privileges.[35]

Cancer and Diagnostic Instruments

From the late nineteenth century, there was a rising medical and popular interest in and anxiety about noncommunicable diseases.[36] Cancer, in particular, stimulated research and therapeutic experiments after the microscope drew attention to cellular pathology, well before it was recognized that cancer was rising among the causes of death.[37] Canadian physicians read international statistics with concern, and their own studies confirmed that mortality from the disease was rising. For example, Saskatchewan figures showed an increase in the death rate from cancer from 8.8 per 100,000 in 1905 to 55.2 per 100,000 in 1928.[38]

The causes, indeed the manifestations, of cancer were puzzling and dreadful. Was it a disease born of

local damage or disorder that then spread to secondary sites, or was it a malfunction of the whole system, such as a contagious disease, so that multiple tumours could develop independently?[39] Today, we know that cancer begins as a genetic change in a single cell; that this cell multiplies and its clones either develop into a tumour or they migrate through the blood system to infect organs distant from the original site. If the cancer takes the form of a localized tumour, it can be excised by surgery, and radiation is used to stop the spread of new cells. If the cancer metastasizes, only whole body treatment, usually chemotherapy, can be effective in saving the life of the patient.[40]

In the first half of the twentieth century, doctors had limited means of confirming the presence of cancer, determining its extent, and providing treatment, particularly for cancers seated in organs and deep in the body. Most of the body was inaccessible. In the same way that the stethoscope was used to improve the doctor's hearing, other early scopes were developed to help the physician look inside the body through its natural openings, for cancer among other conditions. However, the first attempts to see deep into the body were usually dangerous and painful for the patient, as the case of Alexis St Martin suggests. St Martin was a French Canadian who suffered from a permanent gastric fistula (an opening from the outside of his body into his stomach) as a result of a musket wound received in 1822. Unable to work any longer as a voyageur, he became a servant to his doctor, William Beaumont. St Martin consented to hundreds of experiments on his stomach and digestive processes. Beaumont published the results in a groundbreaking physiological study in 1833 and now owns the sobriquet "the father of gastric physiology."[41] St Martin's story reminds us that the history of medical technology and scientific knowledge depends on the experiences and contributions of patients as well as doctors and inventors.

Endoscopes, or instruments for viewing inside the body through various apertures, appeared regularly in research and practice in the mid-nineteenth century. These scopes provided only imperfect views of the stomach, abdomen, lungs, or voice box, owing to limitations of materials and poor illumination.[42] Early instruments were made of inflexible components that could not follow the typical body's dark, soft, and sinuous passages: the first person to receive an endoscope into the stomach, by mouth, was a sword swallower![43]

Gradually, specialized endoscopes were designed for every body aperture: gastroscopes, laparoscopes, bronchoscopes, hysteroscopes, and laryngoscopes are examples. Flexible tubes, electric light bulbs that were small enough to insert into the body, techniques that inflated organs with air and other media to allow easier viewing, and optical lenses improved their viewing function. As with the ophthalmoscope, the clinical utility of endoscopes was greatly enhanced when they were able to combine viewing with other tasks: what could be seen could be manipulated, and doctors appreciated the possibilities. At a meeting of the Montreal Medico-Chirurgical Society in 1910, a Dr Campbell displayed "Goldsmith's Urethroscope" and recommended its use for viewing the urinary tract. A colleague commented that he preferred Vallantin's model, which "could also be used for treatment."[44] The latter device probably had a channel that allowed the insertion of surgical instruments or medication (in this case, for treatment of syphilis). Channels could also be used to retrieve tissue and to collect fluid such as urine, and the instruments became more common when urinalysis became standard laboratory work in the 1920s. The use of the cystoscope spawned auxiliary apparatus, such as special chairs for patient or doctor that optimized the view of the physician.

If early scopes were not useful in diagnosing cancers far inside the body, early X-ray machines were also inadequate for visualizing soft tissues. Further, many doctors resisted X-ray diagnostics because they insisted that detection of cancer was an art. They considered that physical examinations (looking at lesions and feeling lumps) with or without histological tests (biopsy of the tumour followed by pathological study of the cells in the laboratory) were more reliable than images, if not infallible.[45] Radiologists began to collaborate with industry on developing improved X-ray technology. In what one historian has called a "symbiosis of interests,"[46] industrial designers such as Thomson at General Electric incorporated improvements suggested by radiologists to overcome diagnostic limitations and practical problems. With their sales forces and expertise in components such as light bulbs, GE and other manufacturers developed new and better X-ray tubes (hot cathode high-vacuum tubes in the 1920s), high-frequency coils, excitation apparatus, interrupters, and other accessories.[47]

One area of technological improvement was in the image media for X-ray machines that provided a record of the view inside. The first media were large (fourteen by seventeen inches was common), expensive, heavy, and fragile glass plates. According to Godfrey Gale, Dr F. Pepperdene of Toronto encouraged Eastman Kodak to substitute gelatin film for the glass plates. The thinner, lighter, cheaper film was being used by 1919. However, the early films, made of cellulose nitrate, were highly flammable and caused a fire in a Cleveland hospital in 1929 that killed many patients.[48] So-called "safety film" of cellulose acetate was a great improvement.[49] Film had replaced glass entirely by 1940.

X-ray technology became more important in diagnosing cancer as innovations and refinements in contrast media allowed tissues and organs to be seen more clearly against their surroundings. Further, medical specialization resulted in a host of associated imaging problems and solutions. As early as 1900, neurologists were using X-rays to find brain tumours. By the 1920s, cerebral angiography, a painful procedure in which contrast media (air and later gas) was injected into the ventricles (cavities) of the brain, allowed doctors to "see" more areas of the brain. Arthur Childe, the first neurologist at the Montreal Neurological Institute, was "a world giant in radiology" of the brain.[50] In gastrointestinal imaging, the American physiologist Walter Cannon, from 1897, experimented with ingested bismuth as a contrast medium for X-rays of the digestive system. The use of barium (which replaced bismuth), lipiodol, and uroselectan also allowed X-rays to "see" internal organ lesions. In 1927, the first injected contrast agent was used in an X-ray of the urinary tract.[51] The same year saw the beginning of angiography, the study of arteries, as sodium iodide was injected into the arteries that supply the brain to make the brain more visible.[52]

Surgical Treatments for Cancer to 1950

Surgical therapy for cancer expanded with battleground experience and with antisepsis in the last part of the nineteenth century. The saws and scalpels of surgeons whose abilities were honed in the wars of the nineteenth century could remove gangrenous limbs

Figure 7. *In this undated photograph, a woman's gastrointestinal tract is being examined by means of an X-ray machine with fluoroscopic attachment. The development of fluoroscopy and ingestible contrast agents allowed doctors to visualize the soft tissues of the body.*
(CSTMX19598)

and surface tumours, but until Lister, and asepsis, and antisepsis, the patient often died.[53] A. E. Malloch of Hamilton was the foremost of many Canadian doctors trained in Scotland under the surgeon Joseph Lister; he and others imported Lister's 1868 prescription of irrigation by carbolic acid to prevent putrefaction, and thereby saved many lives.[54] Still, the procedure was harsh and not without risks. Lister gradually accepted that the greatest danger of contamination came not from the air but from the patients' and surgeons' tools, clothes, and hands. By the late nineteenth century, the practice of drenching the operating room in a "thick Scotch mist" of vaporized carbolic acid was abandoned, as dry heat-sterilized cotton dressings and instruments became more common.[55]

The dictates of asepsis (maintaining a germ-free environment) and antisepsis (preventing infection) meant that instruments as well as practices used by physicians and surgeons changed, though slowly, beginning in the last quarter of the nineteenth century.[56] Physicians had been slow to accept Semmelweiss's prescription of washing hands and instruments between patients or between bedside and autopsy table. The historian Audrey Davis contrasts the pearl-handled and engraved, but chipped, rusty, mucus- and blood-encrusted instruments of pre-Listerian surgery with modern doctors' tools, which were "plain, unadorned, utilitarian, and sanitary."[57] The former may have affirmed the physician's gentlemanly status, but the latter proclaimed him a man of science.[58] In doctors' offices, general physicians began to adopt hygienic methods in the maintenance and use of their tools. Dr Abraham Groves of Fergus, Ontario, considered himself a pioneer in 1873 when he started to boil "every instrument and all things used in an operation," including his amputating knife.[59] Disposables such as wooden tongue depressors and ready-to-use surgical dressings and catgut sutures simplified cleaning routines. Eventually, most stethoscopes were kept clean in their own cases, and not in the inside of the physicians' tall hats![60]

The demands of hygiene drove changes in hospital operating room design, technology, and routines. There were no more blood-caked surgeons' frock coats, and no students or other observers in street clothes wandering around during operations; sterile linens and smooth easy-to-clean surfaces, plus separate scrub-rooms (by the 1920s), were standard in the new operating suites in hospitals designed by the Toronto office of architects Stevens and Lee.[61] The sterilizable gown, cap, and gloves came into use in operating rooms after 1890, though adoption was uneven.[62] (In the early 1920s, the chief surgeons of the hospital in Lindsay, Ontario, and of the Royal Victoria Hospital in Montreal were still refusing to wear the awkward rubber gloves while operating.)[63] The cause of asepsis was further advanced by new materials such as stainless steel alloys (introduced about 1912) and hardened plastic that could be heat-sterilized. New one-piece instruments could be sterilized by steam in metal autoclaves, or by boiling water in portable sterilizers. In the United Kingdom, at least, doctors and hospitals were able to acquire large quantities of modern surgical instruments at cheap prices when the end of the First World War made them surplus.[64] As J. T. H. Connor notes, the Victorian revolution in surgery changed the relationship between surgeons and their tools. "The development of large-scale medical technology helped to shift the surgeon-doctor from the realm of independent skilled artisan to the world of corporate, mechanized medicine.... As the range of equipment used became more complex and the challenges of sterilization, maintenance, and operation became overwhelming, increasingly it would be the hospital that owned and supplied surgical instruments and apparatus."[65]

Diagnostic devices and the advent of asepsis (to control infection), hemostasis (control of bleeding), and anaesthesia (control of pain) gave surgeons reason, time, and confidence to explore the body. From about 1880, doctors regularly performed gastric and bowel operations. They excised diseased interior parts such as appendices and kidneys, brain tumours, ectopic pregnancies, and gallstones.[66] In the same period, the development of a reliable frozen section technique, using a carbon dioxide freezing microtome, allowed surgeons and pathologists to examine tissue under a microscope and determine whether a tumour was malignant or benign, within minutes, during the course of an operation. This technique, plus the practice of preoperative biopsy, spurred much higher rates of surgery.[67] Accordingly, doctors began to tackle cancer with aggressive procedures that reflected their confidence and ambition. Surgeons celebrated the advent of their new age in 1882, when the American surgeon William Stewart Halsted pioneered the radical mastectomy for breast cancer. Halsted removed not only his patient's cancerous breast but also the chest wall muscles and axilla in an attempt to pre-empt the spread of the disease. The radical mastectomy became the standard procedure for all breast cancers by 1915, and symbolized surgeons' reorientation from symptom relief to attempts to cure the disease.[68]

Yet "the knife" had its critics. In 1915, one venerable surgeon of the era of conservative surgery considered that "there is much unnecessary operating because now most operations are comparatively safe."[69] While surgeons were claiming cures based on limited criteria (how many cancer-free months or years meant a cure?), others were noting that longer-term post-operative survival was more elusive. Surgery seemed completely ineffective in advanced cases or for tumours

deep inside the body. Coupled with the mutilation that radical mastectomy brought to women, dissatisfaction with cure rates opened the way for an alternative (or sometimes tandem) treatment — radiation therapy.

Radiation Therapies: Radium Therapy and Teletherapy

Radiation therapy, or radiotherapy, was the second major branch of ray technology, discovered shortly after X-rays' visualizing capabilities were understood. The first time cancer was successfully treated with X-rays was in Sweden, in 1899. The historian Patrice Pinell suggests it was "a stroke of good fortune"[70] for X-ray technology development that "light therapy," as it was first called, was tried first on skin cancer, because tumours deep in the body did not respond as positively. It seemed miraculous that the disease could be treated without surgery. At the turn of the century, hopes for the X-ray were high; a session of the Canadian Medical Association annual meeting in 1902 was titled "The X-ray as a Therapeutic Agent."[71]

In the first decades of the twentieth century, therefore, many doctors acquired X-ray machines for their offices for therapeutic as well as diagnostic purposes, to treat a wide range of conditions from cancer to cataracts to acne to tonsillitis. Eventually, however, in the words of Edward Shorter, "radiotherapy meant a giant step indeed away from the doctor and his little black bag."[72] By the 1930s, it moved treatment out of the doctor's office because the technology became extremely expensive to acquire and maintain, and because X-ray therapy needed a reliable supply of electricity. As in Winnipeg during the first decade of the new century, hospital electrotherapy departments (where electric baths and other light therapies

Figure 8. *By the 1920s, operating rooms like this one at the General Hospital in Calgary illustrated the ascendancy of infection control as a core medical strategy. Surrounded by sterile linens and enamelled surfaces, under bright electric lights, the surgeon, anaesthetist, and nurses wear masks and rubber gloves.*
(Glenbow Archives, NA-2600-54)

were offered) often became the X-ray departments because they had a source of power, namely an induction machine, necessary for the X-ray.[73]

Light therapy for cancer and other conditions preceded Roentgen's discovery of the X-ray. A Nobel Prize was awarded to Niels Ryberg Finsen, in 1903, for his work on a device that concentrated short-wavelength lights on lesions resulting from lupus.[74] The Finsen light was a very large and expensive cabinet that treated six or more patients at once. In 1890, the electrotherapeutic departments of the Toronto and Kingston hospitals, among others, treated lupus, malignancies such as skin cancer, and skin infections with high-intensity lights, sometimes successfully.

A different type of radiotherapy used radium, a radioactive element discovered by Marie and Pierre Curie, and became the main non-surgical cancer treatment in the 1920s and 1930s. In 1898, the Curies discovered that cancer cells could be killed (and normal cells would not be) through gamma radiation when radium was nearby. Word of this amazing result spread quickly. Dr William Aikins of Toronto, the first major radium therapist in Canada, opened his Radium Institute in Toronto in 1910 and treated patients from across the country. Aikins became the first president of the American Radium Society, in 1916.[75] Radium was soon preferred over X-rays as the stronger source of treatment for skin disorders and cancers; the gamma rays that radium emits provided higher levels of radiation than conventional machines of the day.

As Charles Hayter points out, to communities and hospitals, the prestige of offering this latest technology was almost as important as the medical benefits radium treatment could provide. Radium therapy, like X-ray and light therapy machines, became a badge of the modern hospital.[76] However, the ore was extremely expensive. Until the 1930s, it was only available from one supplier in the world, a Belgian cartel. In 1931, pitchblende containing radium was discovered in the Northwest Territories at Great Bear Lake. The ore was shipped to the refinery of the Eldorado Gold Mines at Port Hope, Ontario, and radium was produced there from 1933. Canada became one of only two radium suppliers to the world's cancer clinics, and the price of radium dropped.[77] After 1946, Canada's uranium and radium supplies were managed by a crown corporation called Eldorado Mining and Refinery. Its management set up a "filling" operation, "a workshop where radium could be prepared in various forms for medical and industrial uses."[78]

Public demand for radium therapy plus the insecurity of its supply encouraged government investment in cancer care in most provinces by the 1930s.[79] The drop in radium prices in that decade also encouraged the process. Quebec provided the first instance of public funding of cancer treatment and research in Canada through the provision of radium treatment.[80] In 1920, just six years after the Radium Institute of Paris was founded, the Institut du Radium de Montréal was established, headed by Dr Joseph-Ernest Gendreau, a French-trained doctor and physicist. Gendreau published many articles on radiotherapy in the 1930s. Charles Hayter argues that Gendreau and the provincial government hoped that the institute would bring Quebec economic prosperity as well as social improvement. (These goals also underlay federal involvement in natural resource development and the founding of the National Research Laboratory for industrial and applied research in 1928.)[81] The institute treated many indigent patients, but conflicts between its research and therapeutic roles, hostility from local clinicians, and unstable funding caused its decline.[82]

Figure 9. *Treatment room, Institut du Radium, Montreal, 1935. The institute was established in 1920 to treat indigent and paying patients and to showcase Quebec medical research. Though expensive, radium therapy was used widely to treat non-malignant disorders, and skin and other "shallow" cancers. The amount of radiation absorbed by the body was not known until the 1930s.*

(Division des archives, Université de Montréal, Fonds de l'Association des diplômés de l'Université de Montréal [P0017], GP0017050201)

Saskatchewan also has a valid claim for leadership in cancer therapy. In 1930, the Saskatchewan government instituted the first provincial cancer control program, with free radium treatment on

medical referral. (Saskatchewan was also the first province to fully fund treatment for tuberculosis patients, in 1929, and later to provide a hospital plan and free medical insurance.) The communitarian values of its farming society may explain the strength of the province's voluntary sector as well as its commitment to publicly funded medicine;[83] from roots in a Saskatchewan organization founded to educate the public about the disease grew the Canadian Cancer Society, established in 1938.[84]

Despite medical and public enthusiasm, however, radium treatment was dangerous and expensive, and these characteristics encouraged innovative methods of delivery.[85] Radium emitted two kinds of radiation: gamma and beta. The gamma radiation that attacked the tumour had poor penetrating powers, and delivery mechanisms reflected that. Small amounts of radium were often placed directly on the skin near a tumour, or inserted into the tumour (in the case of cancer of the cervix). Unfortunately, at the close distances required for effective treatment, the beta radiation was very damaging to healthy tissue. This problem was amplified because doctors could only estimate the amount of radiation the patient's body was absorbing until scientists worked out methods to calculate dosage in the 1930s.

At the Toronto General Hospital, Gordon Richards, the first head of the Department of Radiology in 1919 — and sometimes called the founder of Canadian radiotherapy for his role in its development as a medical specialty — tried to minimize the side effects of radium therapy. He worked with engineers, physicists, and technicians to improve the apparatus and ancillary devices. Richards devised a cotton "radium jacket" into which were sewn about a hundred radium needles for the treatment of breast cancer that had invaded the chest wall.[86] The jacket increased the comfort of women undergoing treatment for breast cancer after surgery. In another effort to minimize side effects, teleradiumtherapy, or radium treatment at a distance, was attempted through "radium bombs," expensive machines with lead shields containing several grams of radium. However, the fragility of the machines required knowledge of physics and constant repair. Further, radium's low radiation made these machines ineffective.

To make the most of financial investments in radium, radon gas was harnessed as a second source of gamma radiation. As Charles Hayter explains, "In undergoing radioactive decay, radium emits a gaseous byproduct, radon, which itself emits gamma radiation as powerful as that produced by radium. If radium salts are dissolved, the solution produces a continuous output of radon gas which can be siphoned off."[87] Radon gas offered two main advantages over radium: it was safer because it had a much shorter half-life; and distributing only radon gas allowed the expensive radium itself to remain permanently available in a central and secure location. At first, the radon was ingested or inhaled by patients.[88] Later, the Harvard physicist William Duane and surgeon Henry Janeway invented a method of capturing the radon gas in glass needles, which were then inserted into tumours or lesions and were much smaller than radium needles. The use of "radon seeds," a preferred method by the 1920s, is an example of brachytherapy, or sealed source radiotherapy.[89] Brachytherapy was also accomplished through gold needles filled with radium or through moulds laid against the skin.[90]

In Canada, apparatus to produce blue radon gas, known as an emanation plant, was built at the Institut du Radium in 1923 — one of only five emanation plants in North America at the time. After a few years, ethnically underwritten disputes between French and English hospitals in Quebec over supplies of radon led to several hospitals developing their own emanation plants, starting in 1929. John Newman, owner of General Steel Wares in Montreal, donated $50,000 for this purpose to the Montreal General Hospital.[91] Other Canadian radon gas plants in hospitals and universities were designed and built in Halifax in 1926, Saskatoon in 1931, and eventually Toronto in 1933.[92]

Besides radium, the other major type of radiotherapy, teletherapy or high-voltage radiation, was a distance therapy that delivered stronger radiation than radium bombs. External light beam therapy was first imagined by Perthes in 1903 but could not be attempted until manufacturers could provide machines capable of delivering continuous currents of high voltage.[93] In 1921, Richards at the Toronto General Hospital was the first to treat a patient with pancreatic cancer successfully with high-voltage radiation, and the 25 percent reduction in relapses he claimed meant a very high demand arose from all over the province. He was the first Canadian to publish the results of treatment of large numbers of patients and so shaped Canadian practice to Canadian experience rather than to anecdotal or European data.[94] The Toronto hospital's 200-kilovolt machine was used typically for breast and cervical cancer because these tumours were closer to the surface and easier to access.

"Roentgen therapy" was controversial because it was extremely hard on patients, as one unconvinced radium therapist described:

> *Soft Roentgen rays rendered them hazardous agents in cancer therapy, but the nature of the hazards was at first quite unsuspected . . . too late to save many patients from the unfortunate sequel . . . . The noisy racket of the transformer, the noxious gases exhaled from the tubes in*

ill-vented rooms and the retching of nauseated patients created a repulsive contrast to the solemn ceremonies of the surgical amphitheater . . . . Patients were often burned from unexpected leaks and on one or more occasions, it is said they were actually electrocuted on the treatment table.[95]

The dreadful nature of cancer treatment encouraged patients to explore alternative therapies, as described in chapter 5.

Despite the side effects of radiation, many patients across the country feared death and resolved to try bravely for a cure from the high-voltage technology. Hospital records, such as those of the Winnipeg General Hospital, show the growing number of treatments from 1912 to 1927.[96] In 1934, the Ontario provincial government bowed to patient demand and medical pressure and opened the Ontario Institute of Radiotherapy. The machines of the new institute were devised by the Toronto General Hospital team. One was a powerful and heavy 400-kilovolt unit, soon enlarged to treat four patients at once — patients who had to remain motionless for forty minutes. It was manufactured by the Picker X-ray Company of Toronto and funded by a grant from the Ontario government. This machine's higher voltage did less damage to the healthy tissue that surrounded the tumour under radiation.[97]

The speed of adoption of radiation therapies depended more on the local and national structure of the medical profession and the role of the state in medicine in any given country than on the efficacy of treatment. In the United States and Germany, for instance, collaboration between surgeons and radiologists encouraged the expansion of both radiation and surgery, a two-pronged approach for individual patients.[98] In other places, including the Toronto General Hospital in early days, rivalry between surgeons and radiologists kept combined radiation and surgery, or radiation alone, away from patients.[99] Following wrangling between medical specialties in 1931, the Saskatchewan cancer control program offered free radium therapy but

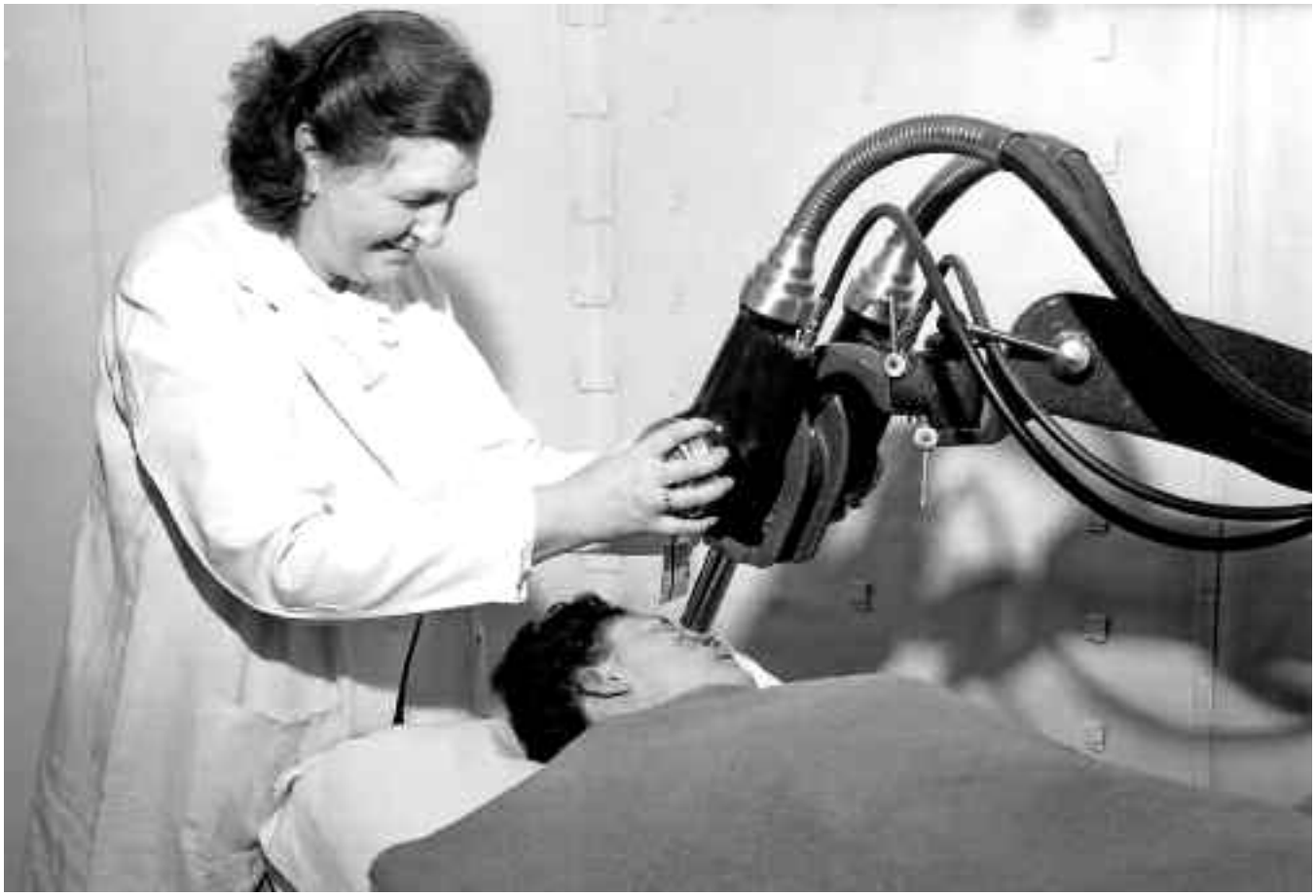

Figure 10. *Specialized, mammoth, and expensive X-ray machines required reinforced rooms and a strong commitment to public funding. In this image from the 1940s, an X-ray technician provides radiation treatment at the B.C. Cancer Institute in Vancouver.*

(City of Vancouver Archives)

not surgery.[100] By 1950 in the United States, most cancer therapy was conducted in doctors' private offices, and radiologists fought against ever-larger and more expensive radiation equipment that would put therapy into centralized university hospitals.[101] In Canada, by contrast, beginning in the 1930s, cancer patients typically received treatments in publicly subsidized hospitals, institutes, and clinics.

Conclusion

The history of surgery and ray technology in the diagnosis and treatment of cancer in the first half of the century illustrates several aspects of the story of medical technology in Canada. Technological innovation rests on the work of hundreds of contributions from academic physicists, technicians, nurses, general practitioners, business owners, and entrepreneurs, many of whose names were never recorded. Tighter ties bound together machines and medical specialists, and technology and hospitals, in developments found all over North America and Europe. At the same time, a range of health care occupational groups formed and reorganized in relation to technology.

The regional variation in the adoption of technologies clearly illustrates that the history of medicine is both a local and a national history: it confirms that cultural features tied to place — politics, the extent of professionalization of the medical profession, the strength of social ties, institutional development, ethnic allegiances, styles of government — are as important in the diffusion and innovation of technology as the diagnostic and therapeutic strengths and weaknesses of the machines and procedures themselves. Saskatchewan and Quebec have both been international leaders in ray technologies and the development of institutions organized around their delivery, but the provinces' successes came out of different medical and cultural contexts.

Despite alarming side effects and poor outcomes, Canadian cancer sufferers and their doctors were willing to try radical surgery and ray-based technologies. Confronted with deadly diseases, most put their faith in modern medical machines. So did the governments, philanthropic agencies, and community organizations that separately and together supported Canadian research and investment in the big machines and poorly understood technologies of cancer institutes.[102]

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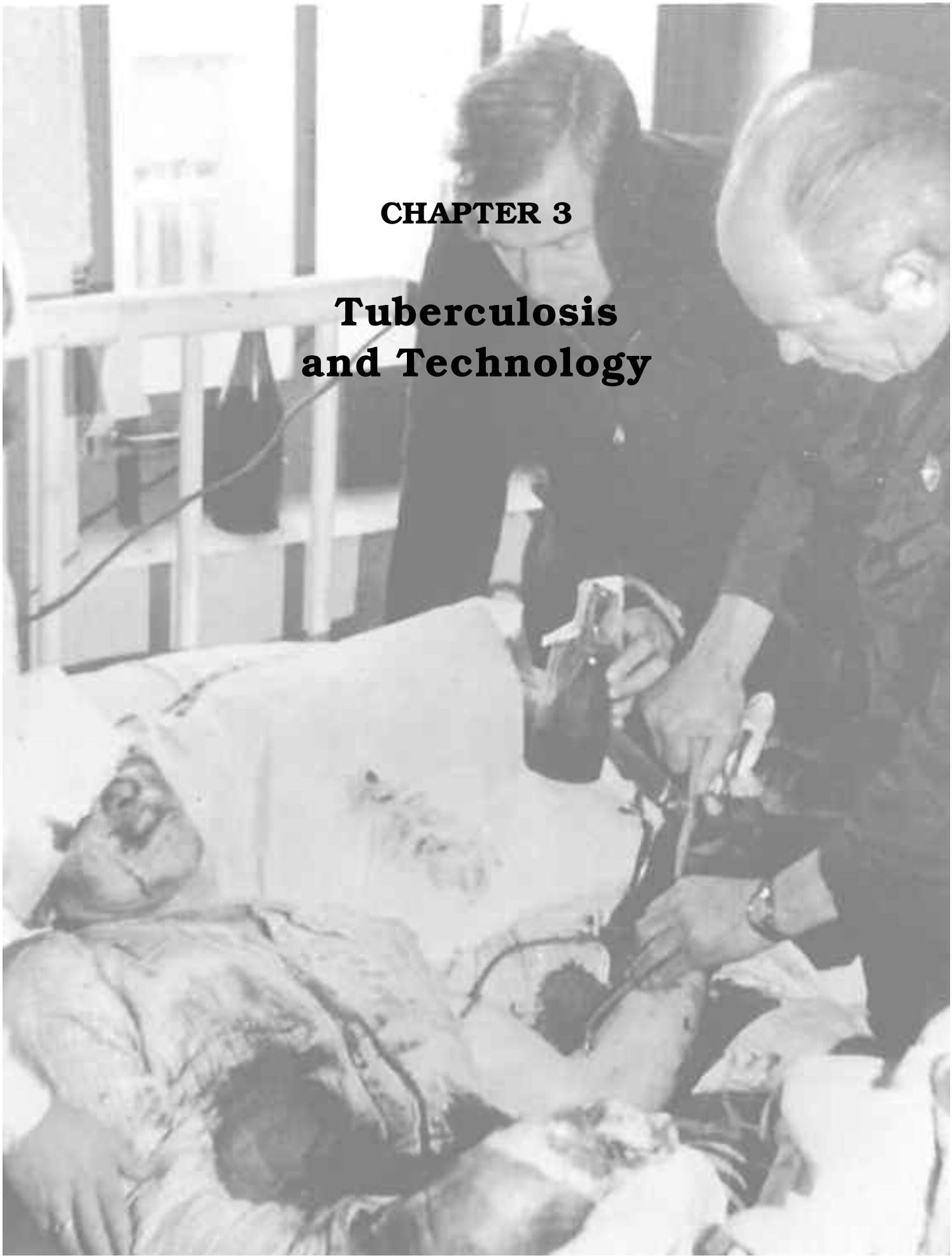

CHAPTER 3

Tuberculosis and Technology

Tuberculosis and Technology

Tuberculosis was the deadliest disease of the nineteenth and early twentieth century in the Western world.[1] In 1900, TB killed between 1,000 and 2,000 of every 100,000 Canadians. Although the death rate had begun to fall in the 1920s, during the Second World War nearly as many Canadians lost their lives because of tuberculosis (36,000) as from enemy action (38,000). In the war years, when incidence peaked, tuberculosis killed more people between the ages of 18 and 45 than all other infectious diseases combined.[2] The many thousands of Canadians who survived active TB were often isolated from friends and family and unable to work for years.

Canadian government officials, scientists, doctors, veterinarians, and the public, therefore, were motivated to control TB because of the human and economic ravages the disease wrought, especially on the young. Their programs utilized an expanding technological armory of instruments, devices, and procedures. The war against tuberculosis enhanced the reputation of Canadians as innovators in research and applied medical science. However, both the ravages of TB and the resources dedicated to it were distributed unevenly among classes, regions, and ethnic and cultural groups.

Tuberculosis was a challenge to prevent and to control because it was difficult to diagnose in its early stages and easily transmitted. The active disease takes several forms. Pulmonary tuberculosis, the most common form among adults, targets the lungs. It causes the development of tubercles (abnormal growths) made up of calcified and fibrous tissue that enclose the invading bacteria, *Mycobacterium tuberculosis*. The disease's progress is marked by a worsening cough with bloody sputum, and can end with a lingering and painful death. TB can also be sited in the bones and joints, the skin, the kidneys, the eye, and the brain meninges. Bovine tuberculosis, identified in 1898, is caused by a slightly different microbe; humans, especially children, can contract it through direct contact and by drinking milk and eating meat from tubercular cattle.

Tuberculosis is contagious but only individuals with active disease can spread the infection. Before the First World War, almost every adult Canadian was infected with TB, though in the great majority, individual immune systems contained the disease and rendered it asymptomatic. The lag between infection and the appearance of symptoms can be as long as five years. Further, TB can be transmitted in several ways. Coughing, sneezing, and talking can launch droplets that can be inhaled or transmitted by touch from surfaces. Dried sputum is a lurking threat, for it retains its infective powers for months. Tuberculosis is also autointoxicating: a patient in whom the disease has been long dormant can again become a sufferer of the active disease, if a tubercle bursts and spreads its germs under stress, exhaustion, or immune system deficiencies. Infection can travel to other parts of the body through the bloodstream or the lymphatic system.[3]

Many Canadian doctors of the late nineteenth century suspected that a germ lay at the root of the devastating malady. In Montreal, William Osler used his microscopes to exhibit the bacillus in a tubercular lung to his medical students within a month of Robert Koch's discovery of the "bacillus tuberculosis" in 1882.[4] In Osler's opinion, Koch's work was, "in its far-reaching results, one of the most momentous discoveries ever made."[5] It reoriented the medical profession's understanding of the disease so that its old symptom-based names — consumption and phthisis, both labels referring to how its victims wasted away, and the "white plague," so-called because of the waxy complexion of its victims — were displaced by the term *tuberculosis*, built on its causative agent.[6] More important, alarmed governments reluctantly accepted that the fight against tuberculosis was a public responsibility.

In Canada, bureaucrats and physicians followed their British colleagues to institute public health measures over the next half century, though funding was uneven across the country and through the years.[7] All levels of government as well as philanthropic organizations were involved in a multi-pronged attack. As Katherine McCuaig summarizes, "Reformers ambitiously attacked tuberculosis on two fronts: bacteriologically — to reduce or eliminate exposure to the germ itself — and socioeconomically, to increase resistance to the disease by improving social conditions, living standards, and general health."[8] In the decades before the First World War, leaders advocated broad approaches that focused on social causes and vectors: clean water, safe milk, and education on hygiene. These were years of dramatic social change, including exploding population, high rates of immigration, and rapid urbanization, and worsening problems such as urban slums, labour unrest, and poverty. Between the wars, "case-finding" and isolation, along with advances in surgery and chemotherapy, were mainstays of the narrower

medical-bacteriological campaign that targeted individuals with active disease. Tuberculosis was arrested through many measures: X-ray surveys to identify the infected, containment of actively ill individuals, public education on hygiene, pasteurization of milk, eradication of bovine tuberculosis, the development of antitoxins and vaccines, institutional and surgical therapeutics, and eventually through chemotherapy.

As Georgina Feldberg notes, Canadian doctors and officials were motivated by the great human and economic toll that the disease took. Tuberculosis struck hard at the industrial labour force and at the nation's children. "The control of tuberculosis was consequently viewed as related to economic and industrial policy that Canadians . . . had already linked formally to the agenda of national research."[9] Consequently, Canadians became world leaders in several aspects of the war against tuberculosis.

Controlling Bovine Tuberculosis

Before the First World War, public health experts, scientists, veterinarians, and doctors turned their attention to preventing bovine tuberculosis, the form that commonly attacked children through tainted meat and milk. One initiative was the campaign for pure milk, discussed in chapter 1. The province of Prince Edward Island and the cities of Toronto and Montreal pioneered the building of pasteurizing plants and legislated that milk sold was to be pasteurized. Tragically, rural children remained at risk decades longer than their urban counterparts. Ontario and Quebec did not make pasteurization of milk compulsory until the late 1930s and early 1940s. The history of pasteurization in Canada is a reminder of the effect of the purely political on the technological: the political clout of dairy farmers, who were opposed to pasteurization, slowed the adoption of this measure in many parts of the country.[10]

Another national program, the identification and elimination of cattle with TB, was made possible through tuberculin testing. Robert Koch announced in 1890 that he had precipitated an extract called tuberculin from cultures of tubercle bacilli. The French physician Charles Mantoux developed a superior test in 1907 that identified infected animals and humans by the allergic reaction their bodies produced in response to tuberculin being injected into the skin. The tuberculin testing of cattle began in Canada before the First World War. The first step was the testing of live animals and elimination of any sick cattle, instituted on a voluntary basis under the auspices of the federal Department of Agriculture (1908). This led to a program of accreditation for herds (1919) and restrictions by geographic area (1923). Cattle that tested positive were destroyed, and only milk from accredited herds could be sold. These policies proved to be successful: the proportion of infected cattle in Canada dropped from 5 percent in the 1920s to 2 percent by 1950.[11] By the end of 1961, all Canadian cattle had been tested, and bovine tuberculosis was almost eradicated.

Diagnosing Active Tuberculosis

Making a definite diagnosis of tuberculosis was difficult until the disease was well advanced. In its early stages, tuberculosis was not easy to differentiate from other lung diseases such as pneumonia or from those that caused wasting, because its early symptoms — fever, loss of weight and appetite, lethargy, generalized pain — are typical of other maladies. But early diagnosis was crucial, because infected individuals could spread the disease, and also because treatment was beneficial, if at all, in the early stages.

One sector with keen interest in detecting tuberculosis was the life insurance industry. Pulmonary tuberculosis was the greatest killer of its insured clients, largely working-class men and women. In response, the Canadian life insurance industry financed education for both health professionals and for the public. In the late 1920s and 1930s in the Maritimes, where tuberculosis death rates were high, the insurance industry directly funded and in some cases controlled public health services through large grants administered by the Canadian Tuberculosis Association.[12] However, in the absence of effective therapeutics, accurate assessment of life expectancy, by detecting active tuberculosis cases, made the difference between profit and loss to the insurance companies.

Diagnostic technology provided only limited help in screening for individuals with active but early tuberculosis. Advanced cases could be confirmed in the laboratory, where tubercle bacilli could be identified in a sputum test or in a gastric washing.[13] Even so, the procedures involved were complicated: the tubercle bacillus was resistant to staining, so several steps of staining, washing, and counterstaining were required. For detection of newly active cases, doctors looked for lung dysfunction: lower-than-average ability to take in or expel air was a marker of tuberculosis and other serious heart and lung conditions.

Various kinds of apparatus were used to assess lung capacity. In one type of test, based on the old technique of percussion, the physician placed the pleximeter, a small disc of bone or other hard material, against the chest, rapped it, and listened through a stethoscope to the sounds produced. However, insurance companies preferred equipment that produced objective and standardized data, independent of the

Figure 11. *The sanatorium of the late 1920s began to look more like a hospital than a rest home. In the laboratory of the central Alberta Sanatorium, Keith District, technicians examined gastric washes and monitored sputum samples to determine whether a "case" was active and infectious TB.*
(Glenbow Archives, NA-2910-21)

patient's account and free of bias from the user of the instrument. With the spirometer, the doctor could compare the patient's lung capacity to standard results. The spirometer utilized a measuring chamber into which the patient exhaled rapidly. Other instruments, the cytometer and stethometer, assessed lung function from the outside by measuring the expansion and contraction of the chest wall during respiration. When it was coupled to ancillary apparatus, the stethoscope became an instrument that produced measurements as well as sounds. For example, by attaching a recording device, visual data in the form of graphs could be generated. However, while all of these devices were more or less useful in identifying diminished lung function, not until the advent of bronchoscopes in the 1930s could TB be differentiated from other lung conditions.[14] These tubes outfitted with lights were inserted through the mouth and into the bronchi, where they could be used to observe the lungs, to biopsy tissue, and to gather pus samples for bacterial testing.[15]

Given the limitations of other technology, life insurance companies, doctors, and patients hoped that the X-ray could be the tool to provide differential diagnosis for lung symptoms. The new machines did expose some signs of TB by showing soft-tissue swelling and thinning of the bones. However, X-rays often missed the tell-tale cavities in the lungs that skilled physical diagnosis could pick up. Although he used the X-ray to diagnose tuberculosis, rickets, and other disease, the Kingston physician James Third warned that the X-ray could not replace physical diagnosis and clinical expertise.[16] In Quebec, French-Canadian doctors preferred physical diagnosis with stethoscopes, following Laennec in France, and did not utilize X-rays for diagnosis of tuberculosis. Even sanatoria, the specialized hospitals for tuberculosis sufferers, were slow to equip themselves with X-rays until after the First World War.[17] Yet in the absence of better strategies, dispensaries added X-ray machines in Montreal in 1909 and in Toronto in 1914 expressly to detect tuberculosis.

As X-ray technology improved, it played a vital role in diagnosing, and therefore controlling and preventing the spread of, tuberculosis. The core equipment for widespread X-ray surveys was not the huge X-ray machines that were housed in hospitals, but their small cousin, the fluoroscope.

Finding Tuberculosis Cases: Mass X-Ray Surveys and the Fluoroscope

The historian C. Stuart Houston marvels that "Saskatchewan, a new province, with new settlers who hadn't really found their feet, was a most improbable place for programs destined to lead North America."[18] Yet communitarian values and strong leadership meant that the province became the world leader in identifying active tuberculosis cases through X-ray technology, through both targeted and mass radiographic surveys. Volunteer and civic organizations as well as government funding were vital in funding and powering all aspects of the campaign.[19]

The high level of infection among Canadians was not understood until sample populations were tested with the Mantoux tuberculin test. The test, however, could not distinguish dangerous individuals with contagious tuberculosis from the huge population of those who carried the infection. That is, those who showed positive had been infected with the bacterium but were not necessarily harbouring active disease: only a minority of those exposed to the bacillus would develop the active disease.[20] Further, the tuberculin test was not always reliable. However, authorities were stunned to find that more than 56 percent of a sample group of Saskatchewan schoolchildren tested positive for infection in 1921. Sampling and surveys of miners and other industrial workers were conducted in the 1930s, using the tuberculin test with X-ray follow-up of those who tested positive.

Fears about the extent of the infection led to the mass X-ray surveys that were launched in 1941 in Saskatchewan and continued throughout much of Canada into the 1950s.[21] Case-finding by X-raying whole populations of cities and provinces only became feasible with improvements in X-ray film and in imaging machines. Miniature X-ray films replaced older plates at about one-tenth the cost, were easy to store, and were effective in finding active cases in the minimal stages. The improvement in films was paired with better fluoroscopes, a progression to which Canadians made significant contributions. Like the conventional X-ray machine, the fluoroscope also made images that were shadows caused by X-rays passing through the body. However, instead of directing the X-ray beam in one burst as in conventional radiography, in fluoroscopy the X-ray beam is continuous or pulsing. Therefore, whereas the X-ray machine produced a still image, the early fluoroscope projected the image onto a screen in "real time." Doctors holding the machine or wearing it strapped to their foreheads could look directly at the screen to see the living and moving image of the patient, who was positioned between the ray and the screen.

Observers expected that the fluoroscope's small size and cheap operation would supplant the X-ray, but the technology had disadvantages. The early fluoroscope images were of lower diagnostic utility than X-ray images. Further, the device could only be used in a dark room because the image was faint; the screen was coated with calcium tungstate, which gave off a faint greenish light when struck by the roentgen rays. Doctors were forced to wear "red goggles" (invented in 1916) to adapt their eyes to the low levels of light required for examination of the fluoroscopic image.[22] Lastly, the imaging could not be captured on paper or film for comparison over time, or for review.

The potential of fluoroscopy changed dramatically from the 1920s due to the creative work of Robert S. Connell, a worker at Fort Qu'Appelle Sanatorium, Saskatchewan. Connell contributed many inventions and innovations to imaging and other sanatorium technology. For instance, he devised an early database management system for card and film identification. Sanatoria, hospitals, and health authorities in this period were adopting scientific management goals and procedures, a core technological development for medicine, according to the historian Joel Howell.[23] Their administrative procedures and record-keeping routines gave them improved information on the success of the campaign against tuberculosis. (However, timely and accurate record-keeping remained a hard-to-enforce goal in many institutions: the minutes of one Vancouver hospital board are spotted with laments that "histories are not being properly written.")[24] Connell also helped earn for Saskatchewan the distinction of being the first North American jurisdiction to develop mobile X-ray units, important for delivering the technology to isolated communities.[25] He also improved the quality of X-ray images, dramatically increased the speed of the process, and ensured the utility of the images produced.

Connell's most significant work was in fluoroscopy. He developed an early version of the photofluorograph, a machine that combined the portability of the fluoroscope with a photographic capacity by using a 35 mm camera with an improved lens and processing equipment.[26] He took his design to Picker X-ray of Vancouver, where he worked for a number of years.[27] Connell's innovations also improved the safety of the fluoroscope. Early fluoroscopes, more than radiographs, took a toll on the first operators before the dangers of irradiation were appreciated. The lower the voltage applied across the X-ray tube by the generator, the better the resulting contrast in the image, but unfortunately the greater the radiation dose. The first radiology specialist in Western Canada, Dr Inglis, was surprised when he rubbed his itchy face and found his prized Vandyke in his hand.[28] Many of the first generation of technicians and doctors died of

cancer, some apparently resigned to be martyrs to scientific progress.[29]

One Canadian victim was Dr F. S. Pepperdene, who studied under Roentgen and Crookes. He started the X-ray program at the Gage Institute in Toronto in 1914. After years of fluoroscoping patients without any protection, no doubt often putting his hand into the beam to turn the patient for a better view, Pepperdene lost his left arm, then the fingers of his right hand to cancer, and eventually died of the disease in 1933.[30] Operators learned to use lead sheets and protective gloves, but not until the middle of the century when the spillage of radiation was better understood. Connell's photofluorograph was less dangerous to the operator because it produced less scatter radiation. He also shortened the distance between the screen and the X-ray tube, thereby reducing the necessary exposure time.[31]

In the 1950s, fluoroscopy was further improved as the development of image intensification did away with the need for dark surrounds and red goggles. Used with barium compound, fluoroscopes still deliver the preferred images of the digestive tract. In addition to medical usage, the fluoroscope was a popular selling feature in Canadian shoe stores to check the fit of new shoes on the feet. The shoe-fitting fluoroscope is an example of the transfer of medical technology to commerce for non-medical purposes.[32]

Containing Tuberculosis: The Sanatorium

Once a diagnosis of active tuberculosis was made, what then? The core strategy from the turn of the century until the 1950s was the sanatorium, both for containment of the disease for the safety of the public and for treatment of the individual. It proved to be an imperfect, inequitable, and expensive approach to both problems.

The first hospital for tuberculosis patients in Canada was the Muskoka Sanitarium, opened in 1897 for paying patients, but Nova Scotia in 1904 established the first state-operated sanatorium in North America.[33] The Muskoka institution was funded by public and private monies, under the leadership of the National Tuberculosis Association, the first entrant in a voluntary sector that grew dramatically between the wars. The National Tuberculosis Association, based in Ontario,

Figure 12. *Saskatchewan sanatorium worker Robert Connell's innovations in fluorography helped to usher in mass X-ray surveys against tuberculosis in the 1940s. This first version of Connell's apparatus allowed nurses and doctors to identify active cases quickly and cheaply, and thereby reduce the spread of infection.*
(Lung Association of Saskatchewan)

soon opened free hospitals in Toronto (for the "consumptive poor") and Gravenhurst and later expanded to include patients with advanced tuberculosis.[34]

Public awareness that many First World War veterans had tuberculosis, coming after studies that showed that the health of recruits was generally poor, injected federal dollars into sanatorium construction as well as hospitals and clinics for treating the tubercular. Sanatoria were built in every province, with Saskatchewan the first province to provide free treatment, in 1929. Special hospitals for children with tuberculosis were also opened: the Queen Mary Hospital, built in Toronto in 1912, may have been the first in the world.[35] By the 1920s, the Christmas Seal campaign led by local service clubs paid for apparatus and improvements for the lives of tuberculosis patients. Civic groups were also committed to the campaign.

However, bed shortages for all ages of patients were chronic. There were beds for only about 15 percent of those with active disease in 1919.[36] The urban poor were more often diagnosed, treated, and otherwise helped (for instance, by visiting nurses) through publicly funded dispensaries, the first of which opened in Montreal in 1904.[37] During the Second World War the bed shortage was acute, despite almost ten thousand sanatoria beds across the country: "There were still twice as many deaths from tuberculosis outside the sanatoria as in them, with 3,500 to 4,000 people dying yearly at home."[38]

Figure 13. *Ultraviolet ray treatment was a multi-purpose therapy, not only for infections of the throat and mouth, as this advertisement shows, but also for skin disorders and as a general bactericide in the war against germs.*
(*Canadian Medical Association Journal* 15, no. 9 [September 1925]: xxxii)

Sanatorium therapeutics changed across the decades but were mostly ineffective. At first, doctors hoped to cure sufferers with physical and medical interventions. Early inmates were expected to follow a regime of exercise to build up their strength and lung capacity. In the late nineteenth century, German clinicians had attempted to increase tubercular patients' lung functioning by forcing pressurized air or anti-bacterial medications into the lungs.[39] However, weakened constitutions and fragile lungs did not benefit from aggressive therapies, and the growing medical culture of therapeutic conservatism led to an emphasis on prevention. Therefore, rest, fresh air, and good food became the cornerstones of care, along with sunshine or artificial light treatment, called heliotherapy.[40] In Ontario sanatoria, the Kromayer lamp (developed in 1904) was used to bathe tubercular ulcers of the throat and neck in ultraviolet light,[41] and sunbathing for natural doses of vitamin D was promoted to kill bacteria and reduce infection. Medical and lay faith rested not in medicines but in the restorative powers of "free, fresh, flowing air," in a phrase typical of the day, and meant that the first sanatoria were built in the countryside.[42] Patients stayed for at least a year, often for several years.

By the interwar period, the cornerstones of therapeutics, in and out of the sanatorium, were bed rest and surgically induced rest therapy, to be described

below. The logic of rest was the fragility of the tubercle. With coughing, exertion, or exhaustion, tubercles could tear, spreading germs both into the air and further into the lungs, where hemorrhage could result. Rest was also necessary to allow the holes or cavities in the lungs caused by the disease to heal and to hasten fibrosis (the formation of tubercles). Strict attention to nutrition was also part of sanatorium routine for the typically thin patients. From the 1920s, new facilities were sited next to hospitals to take advantage of specialist knowledge and hospital laboratories and surgical facilities. As ideas about tuberculosis and its treatment and control changed, the sanatorium began to look more like the modern hospital.[43]

If therapeutics in the sanatorium did not rely on medical apparatus, the sanatorium itself, like the general hospital, depended on sterilization technology and hygienic routines of health care workers. Canadian sanatoria bought big steam and hot-water sterilizing machines from American manufacturers for killing germs on surgical instruments, medical equipment, hospital linens, and patient and staff garments. Companies such as the American Sterilizer Company of Erie, Pennsylvania, had expanded production because of government contracts in the First World War, though most hospitals did not set up central sterilizing departments until the 1920s or later.[44] On the front line of scientific medicine, nurses were responsible for many of these procedures and technologies, from patient-centred hygiene such as the use of linen holders, to sterilization of dressings and gloves, to ward-wide maintenance and cleanliness of everything from floors to surgical instruments.[45]

The sanatorium was meant to model hygienic living to patients, their families, and the general public. It was the command centre of the campaign run by middle-class professional and national organizations (such as the Red Cross) geared to reforming bad habits of tubercular patients and at-risk individuals in the community. Patients were taught that their sputum was infectious and that they could reinfect themselves. They learned the safe ways to cough and spit (using the hygienic technology of the paper cuspidor and sputum flask) and were coached to be clean, cheerful, and as self-reliant as possible in the face of disability. Education was conducted outside as well as inside the sanatorium. William Osler had been a leader in pioneering home care, by arranging visits by nurses and medical students to patients' homes, in 1898.[46] Patients and families were warned against using public drinking cups and issued pocket spittoons, sputum boxes, and cheesecloth with instructions on how to make gauze face masks. Housewives were instructed to use wet mopping rather than dry sweeping to control dust believed to hold bacteria in dried sputa.[47] In schools, children were issued with educative posters and instructed in the "12 steps of hygiene" by the Junior Red Cross. The anti-spitting campaign was the core of the hygiene message; "Do not spit on the floor of your house, workshop or school," intoned a typical placard.[48] In brief, the sanatoria offered "health instruction, moral guidance, and occupational training."[49]

Despite the fact that the great majority of tuberculosis victims were never treated in a sanatorium — treatment was not publicly funded until the 1930s in most parts of Canada, and there were difficulties in "case-finding," as described above — the institution became the model for treatment of the disease. Tubercular individuals who could not afford to stay in a sanatorium were encouraged to "camp" on the porches of their homes or at city dispensaries, or to live in tents in family backyards, with or without insulation and heating. In Toronto, some individuals lived in disused streetcars on the grounds of the "san," even in the coldest winters.[50]

Overall, sanatorium care was expensive, unevenly accessible, and not particularly effective, for mortality rates of at least 50 percent persisted in advanced cases.[51] Although by 1939 death rates from tuberculosis dropped to one-third of what they had been in 1914, certain segments of the population continued to suffer more than others.[52] The sanatorium and the program against tuberculosis were glaring failures in the case of northern Native peoples.[53] In 1950, the Inuit had the highest incidence of tuberculosis in the world, partly because of the disorganized response of governments to northern health issues. The federal Indian Affairs Department often sent Inuit with tuberculosis to sanatoria in the south; as one historian notes, "the largest year-round Inuit community in Canada was situated in the Mountain Sanatorium in Hamilton, Ontario."[54] The Inuit were poorly prepared for the sedentary indoor patient life and diet, the strangeness of X-rays, and other technology they faced. The many incidences of family and economic disruption and tragedy illustrate what can happen when technology (the whole panoply of institutions, apparatus, and practices) does not mesh with its social and cultural context.[55] Even today, tuberculosis still attacks Inuit and First Nations peoples with high rates of infection.[56]

Preventing Tuberculosis: The BCG Vaccine

While the sanatorium, the education campaign, and the fight against bovine tuberculosis were meant to contain tuberculosis by stopping new exposure to the bacillus, until the 1920s there was no method of preventing infection once an individual was exposed. In 1921, two French doctors announced that they had developed an oral vaccine for the prevention of tuber-

culosis by attenuating a form of bovine tubercle bacillus. Called the bacillus Calmette-Guérin (BCG) after the men who introduced it, BCG was developed from live but weakened bacilli taken from cows infected with a strain of tuberculosis that was not as virulent in humans. It was administered first on cattle, then humans, and provided dramatic improvements in rates of infant mortality. Within the year, several Canadian scientists were conducting BCG trials.[57]

Shortly thereafter, the Associate Committee on Tuberculosis Research (ACTR) of the National Research Council of Canada — a newly formed body of government and university research scientists, veterinarians, and physicians — decided that trials of the French vaccine would be an appropriate inaugural project in the fight against tuberculosis.[58] The ACTR co-ordinated and evaluated BCG studies on humans and cattle across Canada for the next two decades, amidst international controversy over BCG's safety and effectiveness.

The international and Canadian medical response to the BCG vaccine was mixed and displayed regional variations. The vaccine was picked up first by the Quebec government, following France's lead. Dr J. A. Baudouin of the Université de Montréal conducted numerous trials of the live vaccine, beginning with one on Canadian infants in Montreal in 1925. Conversely, Ontario was slow to use BCG, perhaps influenced by American concerns about BCG safety, by the lack of controlled studies, or by bias against the French science behind it.[59] Dr J. G. FitzGerald of Connaught Research Laboratories at the University of Toronto suggested its initials could stand for "Better Go Cautiously"; indeed, one strain of the vaccine killed more than seventy children (almost a quarter of those vaccinated) in the German town of Lubeck.[60]

In contrast, in Saskatchewan in 1932, R. G. Ferguson pushed his provincial government for permission to test BCG on the province's aboriginal population. Concerned about the lack of treatment beds, the high rates of tuberculosis mortality on the reserves, and also about dangers to non-aboriginals through contact with Natives, Ferguson felt justified in risking an outbreak of active tuberculosis through vaccination.[61] From 1933 to 1943, he conducted the most scientific trials to date on aboriginal infants and health care workers, again sponsored and appraised by the ACTR of the National Research Council. Ferguson's trials showed that the intracutaneous form of the vaccine was more effective than the oral.[62] In general, the Canadian trials confirmed BCG's effectiveness in conferring immunity with safety and decreasing mortality among close contacts of tubercular patients. After 1948, the vaccine was used extensively across Canada among schoolchildren, prisoners, mental patients, health care workers, and other susceptible groups.

As Georgina Feldberg argues, work on BCG by the Associate Committee on Tuberculosis Research had long-term effects on the institutionalization of Canadian medical research and on Canada's international stature in science. First, the ACTR brought medical research into the National Research Council's mandate: the council in its first years was primarily interested in promoting industrial and agricultural research. By 1927, the tuberculosis investigations were receiving one-third of the National Research Council grants. Secondly, the National Research Council's tuberculosis work set the precedent for organized medical research on a national scale. This was an important development in a country in which the provinces, not the federal government, had jurisdictional authority for health care. Toronto's Connaught Laboratories became a producer of BCG for the world, and it was the main supplier for the United States until 1960.[63]

BCG also boosted medical research in Quebec. A student of Calmette and Guérin, Armand Frappier, the head of bacteriology at the Université de Montréal, supervised many large-scale trials and production of the BCG vaccine. In 1938, he founded the Institut d'hygiène et de microbiologie de Montréal, where BCG and other vaccines were produced for the domestic and international markets. The profits of BCG production fuelled Frappier's immunology research and the development of vaccines against other infectious diseases, including diphtheria, smallpox, and typhoid.[64] Internationally, the BCG research provided both French- and English-Canadian scientists with formal ties to international science and earned the country an international reputation.[65]

Treating Tuberculosis with Chest Surgery

A climate of surgical optimism combined with medical conservatism, the availability of diagnostic devices to justify their invasive solutions, and the absence of other therapeutic strategies encouraged surgeons to attempt to solve the problem of tuberculosis. Surgical "collapse therapies" consisted of a range of operations that aimed to relieve tuberculosis symptoms and put the lungs at rest; the first and most well-known collapse therapy was known as pneumothorax.[66] In 1888, the Italian doctor Carlo Forlanini injected air into the pleural space surrounding a diseased lung to deflate all or part of it, enforce its rest, and starve the bacteria of oxygen. In Canada, an early pneumothorax was performed by J. M. Rogers, a physician in Ingersoll, Ontario, in 1898.

Pneumothorax was improved by the invention of the water manometer in 1911, by which surgeons controlled the amount of air pressure introduced into the chest cavity. Surgeons also depended on a fluoroscope

or X-ray machine to justify and monitor the degree of collapse. By the 1920s, Dr Dobbie of the Weston Sanitorium in Ontario was among the pioneers using nitrogen gas instead of air.[67] After the initial surgery, patients had to get "refills" regularly, sometimes weekly, for more than a year, but they could live as outpatients — and go to work — between treatments. As a result, refill centres were established in clinics, sanatoria, and private doctors' offices, for which special pneumothorax refill apparatus was built and supplied by the Saint John Tuberculosis Hospital, in New Brunswick.[68]

In Ontario, at least, pneumothorax was uncommon until 1927. In that year, Dr Norman Bethune, already a prominent surgeon and now suffering from active tuberculosis, requested that he undergo pneumothorax, also known as compression. He later performed the procedure on many patients in Montreal, where he was the chief thoracic surgeon.[69] "Compression," he wrote, "saves time, saves money, and saves life."[70] Bethune reinvented pneumothorax apparatus. He devised a dozen specialized surgical instruments for lung surgery, including a scapula (shoulder blade) lifter and retractor to hold back the edges of the incision, rib shears, and a lobectomy tourniquet. He also developed an improved procedure (talc poudrage, or the use of talc to promote adhesion in the pleural cavity).[71] Bethune is most famous for developing a mobile blood transfusion system that took blood to the front lines during the Spanish Civil War (1936–39) (previously, wounded soldiers had to be transported to medical centres). He thus helped to save many lives that would otherwise have been lost from loss of blood, in war and later in peace, when his innovations were used to set up hospital transfusion services.[72]

There were other kinds of collapse therapies, some radical. In one version, air was injected into the abdominal cavity, the procedure of choice when lung cavities were located on the base of the lung. Some physicians preferred to temporarily paralyze the diaphragm and therefore prevent the lung from moving by crushing the phrenic nerve, a treatment common in the 1930s. (The nerve would repair itself in time.) An instrument employed in the case of a failed pneumothorax was the thoracoscope. It was used to cut an adhesion of the lung to the chest wall that prevented the lung from collapsing.[73] Bethune, like other chest

Figure 14. *Doctors hoped, usually futilely, that collapsing a tubercular lung would allow it to rest and heal. During pneumothorax, the surgeon injected air or gas into the pleural cavity, while using a manometer to monitor intrapleural pressure.*

(Glenbow Archives, NA-2910-19)

surgeons at large urban hospitals, also favoured a permanent form of collapse therapy that involved removing from three to eleven ribs (thoracoplasty). This procedure was first performed in Canada in Montreal by surgeon Edward Archibald in 1912.[74] From the 1930s through to the 1950s, between 30 and 60 percent of tubercular hospital patients were treated with surgical rest of some form.[75]

In general, however, surgical collapse therapies for tuberculosis had no more success than bed rest, as medical critics pointed out.[76] Thoracoplasty in particular had a high mortality rate from inoperative hemorrhage and post-operative infection, and also resulted in disfigurement. By 1940, surgeons were bypassing collapse surgery in favour of removing diseased lobes and even whole lungs. These radical procedures had become less dangerous because of a Canadian invention. At the Toronto General Hospital, in 1932, Norman Shenstone and Robert Janes developed a tourniquet that allowed faster resection (surgical removal) and resulted in less bleeding. As a result, Toronto became an important centre of thoracic surgery.[77]

Though these procedures were still accompanied by a high mortality rate, major surgery became safer with new techniques and apparatus in anaesthesia pioneered in the hospital and on the battlefield.[78] Early technology had been simple. Victorian doctors had developed their own kits for using ether, the most common anaesthetic agent. Into the 1920s, the apparatus consisted of some version of a wire-framed mask covered with a towel, onto which the ether was dropped from a bottle; a mouth-gag and a wooden wedge kept the teeth pried open. Beginning in the late nineteenth century, various vaporizers were invented to better regulate the concentration of gas inhaled. In Canada in 1887, an ether inhaler that had been in use at the Toronto General Hospital was manufactured and distributed in Toronto by Stevens & Co.[79] In 1919, Sister

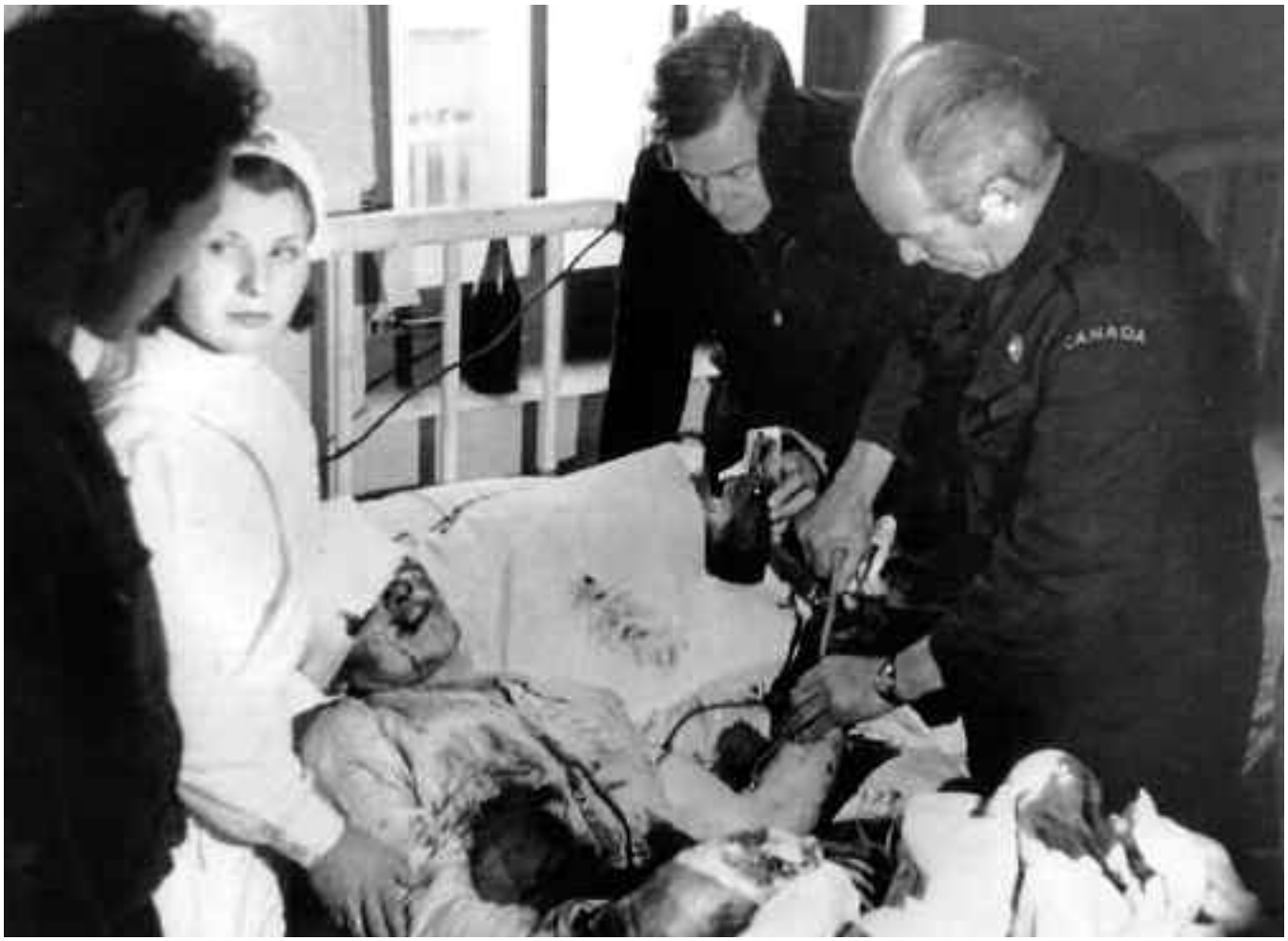

Figure 15. *Norman Bethune (1890–1939) was an innovative surgeon who developed specialized instruments and techniques for thoracic surgery. He also revolutionized military medicine by introducing mobile blood banks and medical units that saved thousands of lives. Here he performs a transfusion during the Spanish Civil War.*
(Library and Archives Canada, MIKAN no. 3194603)

Charles Spinola of St Paul's Hospital in Vancouver, B.C., invented and later patented what she called the "St Charles Ether Vaporizing Machine," which provided a more even flow of the gas to the patient and permitted hospitals to use less gas per surgery.[80]

The practice of anaesthesia was refined as sequences of gases and better monitoring techniques were introduced. In the early part of the twentieth century, a combination of gas and ether became the new anaesthetic standard in hospitals. Typically, nitrous oxide was delivered through a bag and a faceplate until the patient was unconscious, then discontinued as ether was started through a vaporizer.[81] In 1917, in London, England, Henry Boyle improved this procedure with his continuous flow machine that delivered nitrous oxide, oxygen, and ether through reducing valves and a three-way stopcock to a Cattlin (breathing) bag and finally to a face mask. The apparatus included a water-sight flow meter to measure the gas flow and a vaporizer to limit the gas concentration. Boyle travelled extensively through Canada in 1923, and his name, in the opinion of an admirer, became "a household word in anaesthetic circles" in this country.[82]

New apparatus was developed to address other problems of anaesthesia. A common danger, especially when operating on the head, neck, and throat, was that the throat and larynx could collapse and therefore obstruct breathing. In the 1920s and 1930s, Canada led the United States in the introduction of endotracheal intubation to keep the airways open.[83] Surgeons began to blow ether and air through a rubber, silk, or brass catheter inserted into the mouth and larynx and down into the windpipe, to ensure that the patient received adequate anaesthetic and air. The method of ether-air insufflation through a tube meant that the anaesthetized patient's lungs did not need to work during the surgery. However, ether could leak out of the patient's mouth into the face of the operating surgeon, with potentially alarming results. One solution invented during the First World War by Magill involved rubber tubes inserted into both nostrils, one to deliver the anaesthetic and the other to carry off the exhalations of the patient. Another was "an inflatable cuff which could be blown up within the trachea (by a little side tube)," which made the endotracheal system airtight; this also protected the patient from potentially fatal aspiration.[84] Suction apparatus allowed doctors to remove vomit and mucus that could obstruct breathing.

Canadian doctors introduced two inhalational agents and took part in the development of machines that made general anaesthesia safer, though early patients paid the highest price possible. The first agent was ethylene, introduced in 1932 in Toronto. Dr W. Easson Brown had famously wondered, "Since a man can pass out from drinking too much liquor, why not use alcohol in its gaseous form, ethylene, as an anaesthetic?"[85] Brown's test subject was Frederick Banting, the discoverer of insulin. The second inhalational agent was cyclopropane, which allowed deeper anaesthesia in low concentrations. General anaesthesia with the use of this gas was introduced at the University of Toronto in 1929 but was suspended after several tragic deaths in 1930.[86] In 1933, cyclopropane was reintroduced by Harold Griffith of Montreal and an American named Ralph Waters. Griffith worked with the medical inventor Richard Foregger to develop a closed-circuit breathing machine with a precise flow meter, for use with cyclopropane.[87] This model was economical, preventing the expensive gas from escaping in uncaptured exhalations. The "Montreal Model" of the Foregger Metric Gas Machine became the first choice for Caesarean section operations in Montreal and Toronto.[88] Griffith developed other devices for delivering anaesthetic, including a breathing bag that controlled the ventilation of the lungs to remove carbon dioxide and a protocol that drastically reduced the threat of explosions from static sparks around the machines.[89]

Harold Griffith is also celebrated for his introduction of curare as a muscle relaxant.[90] With his resident Enid Johnson in 1942, Griffith was the first anaesthetist to use a preparation of curare in an operation. The E. R. Squibb Company had developed a preparation containing curare, but its reputation as a derivative of "arrow poison," as a paralytic and convulsive drug, had previously frightened away specialists. Griffith's published work showed that curare allowed lower levels of anaesthetic and therefore safer surgeries. The website of the Canadian Anesthesiologists' Society comments that "the introduction of muscle relaxants reduced anesthetic requirements, increased the scope of surgery, improved operating conditions and decreased morbidity and probably mortality."[91] Curare also put the patient completely at the mercy of the anaesthetist: with other anaesthetics, the patient continued to breathe naturally with the assistance of a breathing bag, but with curare, the patient needed artificial ventilation because the muscles were paralyzed.[92] Griffith, looking back over his long career in 1962, noted that anaesthesia had become almost routine because doctors had achieved unobstructed airways through endotracheal tubes and adequate pulmonary ventilation.[93] He might also have noted that since 1938 in Canada, administration of anaesthesia could only be done by physicians (and not by nurses, as had often been the practice). The first independent department of anaesthesia in Canada was created at McGill in 1945.[94]

Despite these improvements in anaesthesia and blood transfusion, surgical therapies for tubercular lungs remained risky and difficult because lungs col-

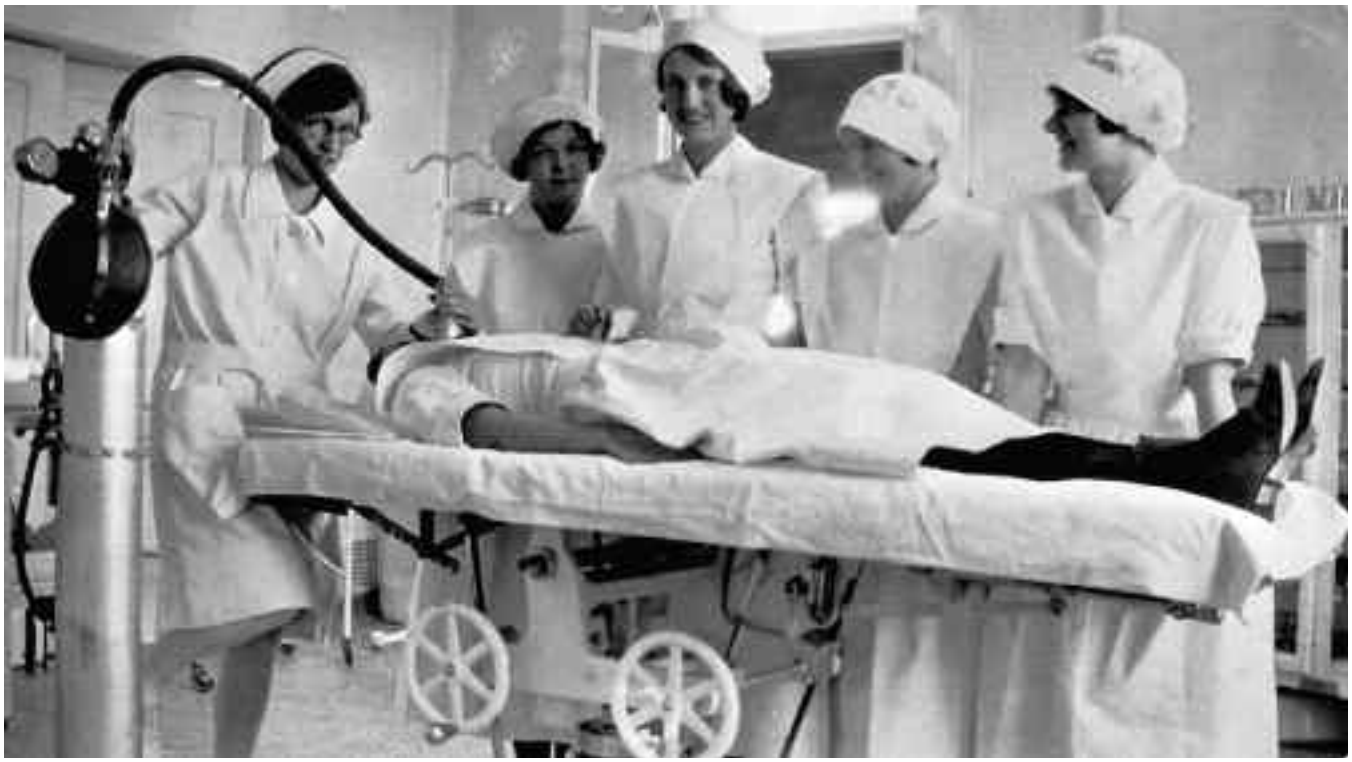

Figure 16. *Nurses often administered anaesthetic during hospital surgery until 1938, when the function became the preserve of doctors. In this staged 1928 image from Calgary's General Hospital, a senior nurse is demonstrating the proper placement of gas cylinders, breathing bag, and face mask.*
(Glenbow Archives, NA-1737-1)

lapsed as soon as the chest was opened. Second World War experience among the wounded did shape a consensus that intubation, cyclopropane, and controlled ventilation were the best practices.[95] However, thoracic surgeries for tuberculosis were discontinued in the 1940s with the arrival of streptomycin, an antibiotic drug that finally offered the medical profession an effective treatment for tuberculosis.

Treating Tuberculosis through Chemotherapy

In the late 1880s, Sir James Grant of Ottawa was one of the first physician-scientists to speculate on the possibility that a by-product of the tubercle bacterium might provide a cure for tuberculosis.[96] The therapeutic ineffectiveness of tuberculin, extracted by Koch in 1890, did not stop researchers from searching for a way to treat rather than to prevent the disease. For instance, in 1902 and 1903, at the J. R. Molson Pathology laboratory at McGill University, the clinical scientist A. G. Nicholls injected virulent tubercle bacilli into guinea pigs, rabbits, and other animal subjects in the search for an antitoxin. Nicholls, like other clinical scientists, dreamed of finding a cure for tuberculosis.[97] Despite advances in therapy with sulpha drugs (which contain the growth of bacteria and allow the body's immune system to fight the micro-organism) and later antibiotics (which attack the bacteria directly), anti-microbial drugs could not easily penetrate the tubercle bacillus because of its "waxy coat."[98]

The first breakthrough was the discovery of streptomycin, developed from a soil fungus by Selman Waksman and others in the United States in 1944, and awarded the Nobel Prize in Physiology or Medicine in 1952. Though streptomycin was effective in killing tubercle bacilli, it had serious side effects and required a lengthy course of treatment, and the rapid development of resistance in the bacillus limited its utility. In the late 1940s, a more effective though still long-term therapy appeared as a combination of two drugs, streptomycin and PAS (para-amino salicylic acid). PAS prevents the uptake of oxygen necessary for the survival of the bacillus. Isoniazid, an inexpensive synthetic compound introduced in 1951, is the key ingredient of a cocktail that is still used against active tuberculosis.[99]

Conclusion

Canadian scientists, veterinarians, and doctors developed new technologies and led the world in the

fight against tuberculosis, through milk pasteurization, control of bovine tuberculosis, mass X-ray surveys, and innovations in fluoroscopy and surgical therapies. Tuberculosis research also kick-started medical research in Canada at the national level. However, until the 1950s, medical science's best weapon in the war against tuberculosis was the prevention of infection. Certainly, many individuals with active tuberculosis were helped by medical technology, in the form of early diagnosis, sanatorium and surgical treatment, and, in the 1940s and beyond, drug treatment for active disease. The mortality of tuberculosis dropped with each decade. The reasons for the decline of tuberculosis are still being debated, but they include early treatment, better nutrition and sanitation, and waning of the strain itself.[100] However, since the 1980s tuberculosis has returned as a serious and growing worldwide threat to health because the bacillus is now resistant to many drugs. In Canada today, social factors and the withering of public health structures have kept the incidence of the disease at high rates among aboriginal peoples.[101]

Despite its relative poverty, Saskatchewan was the first province in Canada to fully fund treatment for all tuberculosis patients, in 1929. (After the Second World War, the province's strong communitarian values were reflected in its pioneering role in providing its citizens a hospital plan and free medical insurance.) Sir William Osler famously said that tuberculosis was "a social disease with a medical aspect";[102] the history of tuberculosis illustrates that the control and cure of the disease required — and still demands — broad social as well as medical commitment to a range of initiatives and technologies.

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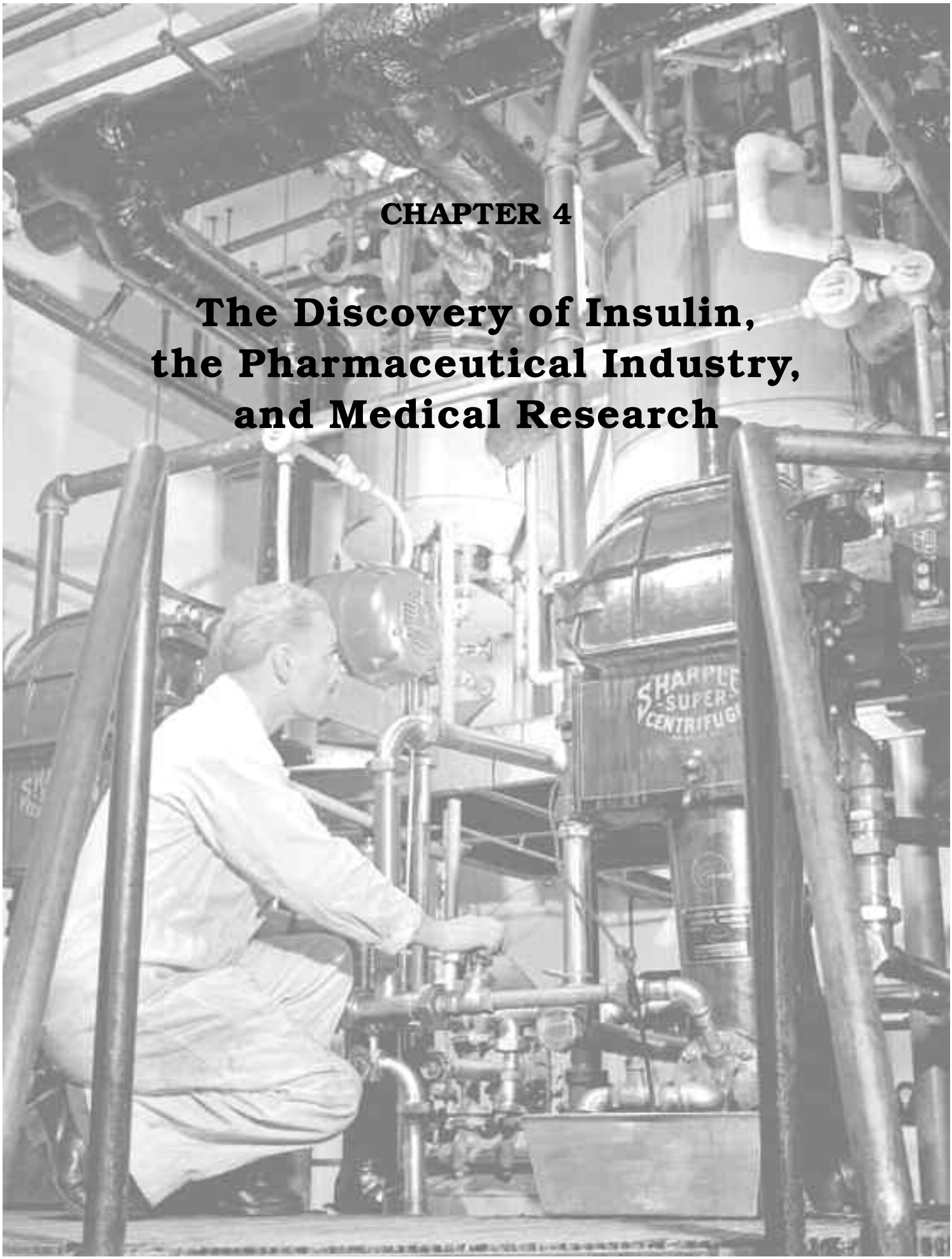


CHAPTER 4

The Discovery of Insulin, the Pharmaceutical Industry, and Medical Research

The Discovery of Insulin, the Pharmaceutical Industry, and Medical Research

The discovery of insulin is heralded as a great Canadian breakthrough and contribution to medicine. Insulin had an immediate impact in the medical world, not as a "cure" for diabetes — something that still eludes us — but as a therapy that saved lives, most notably children's lives. It put Toronto on the map, garnered international attention including a Nobel Prize in Physiology or Medicine, and made heroes of Banting and Best. This event — the discovery of insulin in Toronto — provides a window through which to examine the characteristics of medical research, the process of innovation or discovery, the role of the growing pharmaceutical industry, and the expansion of medical research in Canada as a result of insulin's success.

Diabetes and the Discovery of Insulin

Diabetes mellitus is a chronic disease in which the body either does not manufacture enough insulin or does not properly use it.[1] Produced in the pancreas, insulin is a hormone that is used by the body to transport energy, in the form of sugar (glucose), from the bloodstream into the body's cells. In 1674, Thomas Willis of Oxford University wrote that the urine of diabetics was "wonderfully sweet as if it were imbued with Honey or Sugar."[2] Individuals with diabetes pass large volumes of urine with high sugar content, and thus arose the name "sugar sickness" for this disorder. In 1860, Étienne Lancereaux, a French physician, made the connection between diabetes and pancreatic disorders. In 1889, German researchers surgically removed the pancreas of a number of dogs and discovered that the animals became severely diabetic. By the late nineteenth century, medical researchers realized that understanding the role of the pancreas was the key to understanding diabetes. The pancreas was involved in metabolizing food, specifically carbohydrates, into energy for the body.[3]

While researchers were grappling with trying to understand the functions of the pancreas, clinicians were trying to save their diabetic patients. Individuals with diabetes suffered intense hunger and pain, wasted away from lack of nourishment, and eventually succumbed to a coma and then death. Physicians had little to offer their patients. Some physicians gave their patients sugar supplements (to replace the sugar that was being passed in their urine), but this was unsuccessful. Doctors also used opiates to manage pain in the later stages of the disease. By the early twentieth century, the leading therapy was "under-nutrition," or under-feeding of carbohydrates. Since the body could not metabolize normal amounts of food, doctors attempted to provide only as much food as the body could metabolize. Accordingly, diabetics were put on special diets. It was a "starvation" therapy in which a diabetic's diet was so restrictive that patients usually were unable to maintain normal body weight.[4] The two leading American diabetes specialists of this time — Dr Frederick M. Allen and Dr Elliott P. Joslin — both adhered to under-nutrition as a therapy.[5] Still this therapy did not cure diabetic patients, and diabetes remained a fatal disease.

In Canada, Frederick Banting was preparing to give a talk on the pancreas to medical students at London's Western University in the fall of 1920. The night before his lecture, Banting read an article entitled "The Relation of the Islets of Langerhans to Diabetes with Special Reference to Cases of Pancreatic Lithiasis," in the latest issue of *Surgery, Gynecology and Obstetrics*. Its author suggested that the internal secretion of the pancreas originated in the islet cells. Banting rose in the middle of the night to jot a note to himself: "Diabetus. Ligate pancreatic ducts of dogs. Keep dogs alive till acini [sacs at the end of the pancreatic ducts] degenerate leaving Islets. Try to isolate the internal secretion of these to relieve glycosurea [condition of abnormal amounts of sugar in the urine]."[6] That is, Banting hoped that by tying off the pancreatic ducts, the sacs at the duct end would deteriorate but the islet secretion could be retrieved. Western University did not have adequate facilities or assistance for this research. Within days, Banting contacted Professor J. J. R. Macleod, internationally known for his work in carbohydrate metabolism, at the University of Toronto to discuss possible laboratory support to test his research idea.

The following summer of 1921, Banting moved to Toronto to begin his research. Macleod generously provided Banting with laboratory space, a dozen or so experimental dogs, and graduate student assistance. The story goes that the two graduate student assistants decided to divide the job. Charles Best won the coin toss over Clark Noble to work with Banting for a few weeks, then agreed to stay on for the entire summer.[7]

Banting and Best divided up the research work in the following way: Banting focused on the surgical techniques of depancreatization and duct-ligation while Best worked on measuring urinary and blood sugars, along with other tests.[8]

Banting wanted to provide pancreatic extract to dogs made diabetic to see if they could regain the ability to utilize glucose. According to Michael Bliss, Banting was probably planning to do pancreatic grafting or transplanting of portions of duct-ligated pancreas (with islet cells intact) to dogs whose pancreas had been removed. He was unaware of the problem of rejection, the process whereby the immune system of the recipient attacks the transplanted organ. The French researcher Alexis Carrel had encountered rejection in his transplantation surgery on dogs in the early 1900s. Macleod suggested that Banting also work on preparing an emulsion or extract of duct-ligated pancreas. So the research plan involved both lines of inquiry — pancreatic grafting and preparation of an extract.

As Michael Bliss points out, the research plan was more easily talked about than carried out. Banting and Best were confronted with a difficult work environment, including an unsanitary and uncomfortably warm laboratory. They ran out of dogs on which to experiment and were forced to buy dogs on the street. After three frustrating months, Banting and Best produced some encouraging results. Injections of the pancreatic extract in one severely diabetic dog revived the animal briefly. A second series of animal experiments focusing on the pancreatic extract was then conducted. Macleod cautiously supported Banting and Best, and he told them to be thorough and careful so that others could reproduce their results.[9]

During the fall of 1921, Banting received better laboratory and operating space, more assistance, and a small salary to continue his research. He had made the decision to abandon his fledgling practice in London. Macleod offered more direction, including expanding the research to include longevity studies of the diabetic dogs given insulin. A young biochemist, J. B. Collip from the University of Alberta, on sabbatical at the University of Toronto, joined the insulin team in late 1921 to improve the extract technique and develop a more purified form.[10]

In 1922, the first clinical trial of the pancreatic extract occurred. In January of that year, Collip's extract was injected into 14-year-old Leonard Thompson, a Toronto resident who became the first person in Canada to receive an insulin injection. His improved health provided the best evidence that the Toronto extract was effective. After several other successful cases at the Toronto General Hospital, Banting, Best, Collip, and clinicians W. R. Campbell and A. A. Fletcher published "Pancreatic Extracts in the Treatment of Diabetes Mellitus" in the March 1922 issue of the *Canadian Medical Association Journal*. On the day the article was published, the *Toronto Star* announced that Toronto doctors were "on Track of Diabetes Cure." It was in these first early publications and presentations that the Toronto group began referring to their extract as "insulin."[11]

Shortly thereafter, it became clear that insulin saved lives, though only a few select lives at first. During the late spring and summer of 1922, a handful of starving diabetic children received insulin. On May 21, 1922, James Havens in New York became the first person treated with insulin in the United States. After two weeks of treatment, Havens was able to get out of bed

Figure 17. *The University of Toronto's Connaught Anti-Toxin Laboratories produced large batches of insulin, under the direction of J. B. Collip. This bottle dates from 1923.*

(Thomas Fisher Rare Book Library, University of Toronto, with permission from Sanofi Pasteur Ltd. [Connaught Campus], Toronto)

and walk. "Diabetics swarm from all over and think we can conjure the extract from the ground," wrote Banting in July 1922.[12] The Toronto group chose to treat the most seriously ill, including 14-year-old Elizabeth Hughes (daughter of the United States Secretary of State), who was close to death from starvation. Michael Bliss states that Elizabeth became "the prize patient, not only because of her family's prominence, but also because she had sunk so low and responded so beautifully to insulin injections."[13] Elizabeth wrote the following to her mother:

> *I declare you'd think it was a fairy tale . . . I look entirely different everybody says . . . gaining every hour it seems to me in strength and weight . . . it is truly miraculous . . . . Dr Banting considers my progress simply miraculous, none of his other patients coming near me in diet etc., and so I consider myself especially lucky. He brings all these eminent Doctors in from all over the world who come to Toronto to see for themselves the workings of this wonderful discovery, and I wish you could see the expression on their faces as they read my charts, they are astounded in my unheard of progress . . .*[14]

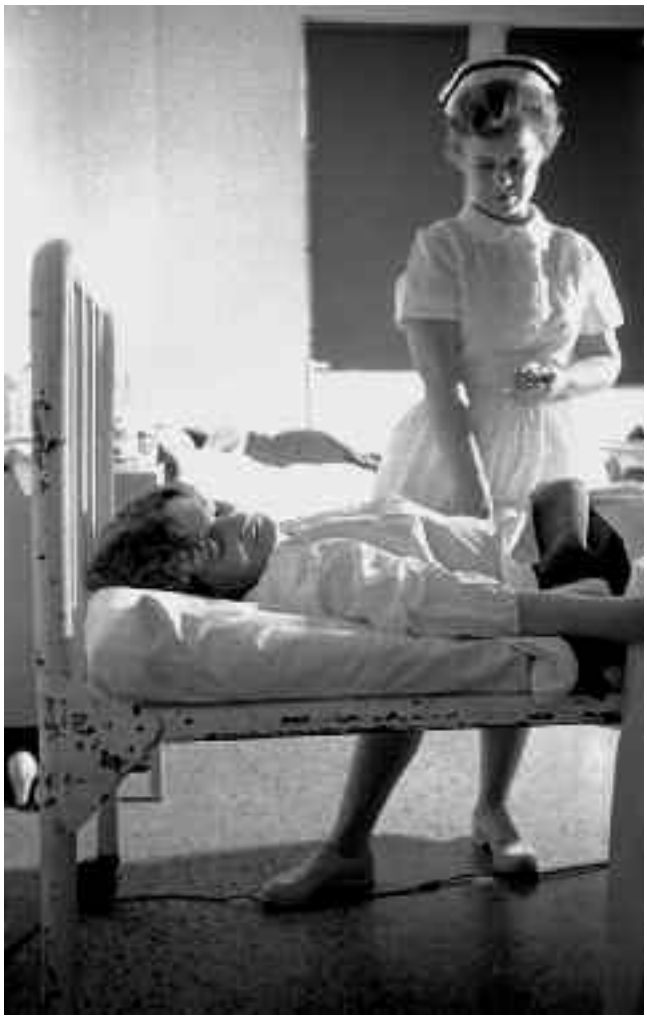


Figure 18. *Patient being treated with insulin. Individuals with diabetes are unable to produce adequate amounts of insulin, an essential hormone that metabolizes glucose (sugar), and die if untreated. The discovery of insulin in Toronto in 1921–22 transformed diabetes from a fatal to a chronic disease.*

(Library and Archives Canada, neg. PA-204847)

The impact of insulin was immediate and remarkable. Dying children were resurrected; diabetics in comas were brought back to life, and otherwise doomed children were given a chance to live into adulthood. Before and after photos of children were almost unbelievable.

As convincingly argued by Michael Bliss, the discovery of insulin was the result of a collaborative research team — Banting, Best, Macleod, and Collip — and not the work of one individual. The 1923 Nobel Prize in Physiology or Medicine went to Banting and Macleod, who in turn shared their award with Best and Collip. Public and professional expectations of more medical breakthroughs thereafter bore down on the members of the insulin team.[15] As noted by Bliss, the first-class research facilities of the University of Toronto contributed to the successful discovery of insulin, which in turn led to further government support for university medical research in Canada (discussed below).

The Rise of the Pharmaceutical Industry

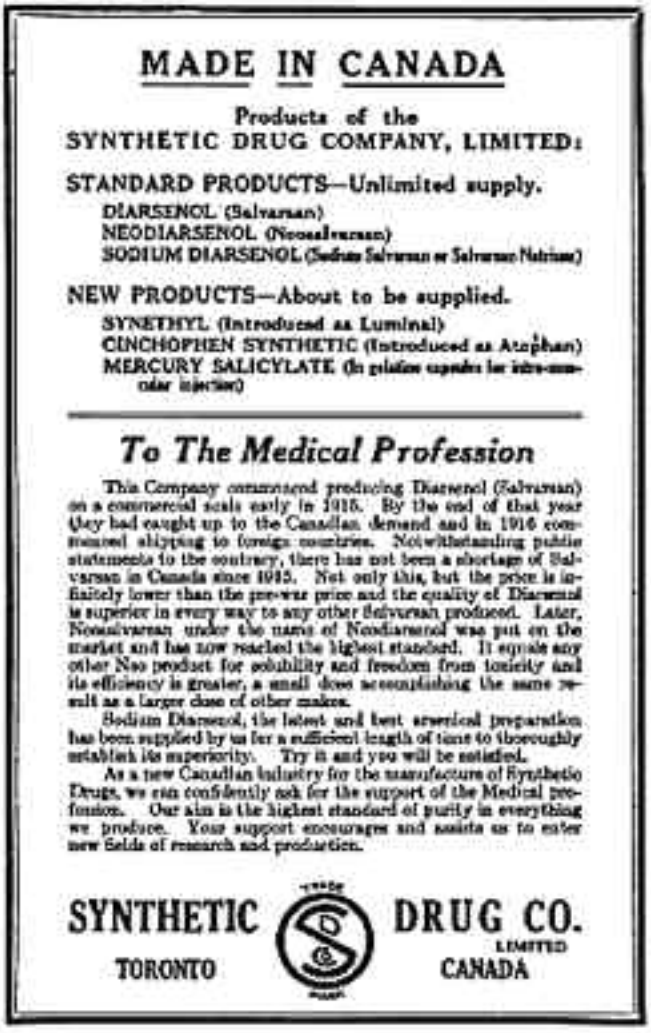
By the end of 1923, insulin was available across North America and in most parts of Europe as a maintenance therapy for diabetes. The story of insulin, therefore, illustrates the technology of applied as well as pure science. Within weeks of the publication of the discovery of insulin, the problem was to produce enough insulin to meet demand. The University of Toronto's Connaught Anti-Toxin Laboratories worked on producing large batches of insulin, under the direction of J. B. Collip, but they had problems. They were able to produce only small quantities at a time, for they lost the extract potency when they expanded production beyond a few cubic centimetres. At one point, there was an insulin "famine," and early insulin patients had to revert to special diets until the insulin supply could be restocked.[16]

To manage supply, specific pharmaceutical companies or research agencies controlled the manufacture and distribution of insulin in each country. Eli Lilly and Company of Indianapolis agreed to work with Connaught

Laboratories to manufacture enough insulin to supply North American patients. Specifically, the American pharmaceutical company contracted with the University of Toronto (of which Connaught was part) for manufacturing rights of insulin for distribution to the U.S. market, from which the University of Toronto received significant royalties. As noted by the historian Jordan Goodman, this was "an association rare at the time but foreshadowing many such relationships in the future."[17] Elsewhere in the world, research agencies and pharmaceutical companies also hurried to produce insulin for their diabetic patients. For example, in Great Britain, the Medical Research Council undertook development of insulin there whereas the pharmaceutical company Hagedorn (later Novo Nordisk) in Demark took the lead on insulin production in that country.[18] This association between the university, local laboratories, giant pharmaceutical companies, and overseas government institutions became a typical set of relationships struck to bring new drugs to the market. It also represented dramatic changes in the pharmaceutical industry and in the structural relationships that supported innovation.

At 1900, most North American pharmaceutical companies were small and uninterested in research and development. They dealt primarily in natural product extracts such as codeine, quinine, and morphine.[19] As late as the 1930s, the range of medicines, ointments, and drugs offered in a typical hospital pharmacy was narrow, in accordance with the limited usefulness of pharmacology. For example the Sault Ste Marie (Ontario) General Hospital stocked only thirty-seven items in 1926, compared to well over a thousand in 1998.[20] Conversely, across the Atlantic, and in Germany particularly, drug companies joined forces with academic researchers to study the composition of chemical compounds, which were then developed into potential medical therapies. Laboratory researchers systematically analyzed various chemicals, such as codeine, nicotine, caffeine, morphine, and cocaine. They also standardized practices for measuring quantities and for achieving consistent strengths, both key for the mass production and marketing of drugs for the pharmaceutical industry. For example, the German company Bayer marketed acetylsalicylic acid (aspirin) in 1900 for pain relief.[21] To counter pathogens, the search began for "magic bullets," defined as "agents that kill germ invaders yet leave a living, healthy patient."[22]

In 1910, to treat syphilis, the German researcher Paul Ehrlich discovered Salvarsan (an arsenic-based drug), which the German chemical company Hoechst subsequently manufactured for worldwide distribution. According to Roy Porter, Salvarsan was the first "magic bullet," for it "did not merely alleviate but actually cured a serious disease." It was not however an ideal cure because of its side affects.[23] Salvarsan's development also marked the beginning of target chemotherapy, because it was the first drug scientifically designed to treat a disease caused by a specific organism (in this case, the spirochaete causing syphilis). Canadians lost their access to Salvarsan when the First World War cut off imports from German pharmaceutical companies. In response, domestic laboratories began to manufacture their own versions of the drug to assure supplies. Thus, in 1915, Diarsenol and associated drugs were produced by the Synthetic Drug Company, whose principals enjoyed close links to the medical elite. The company's drugs were tested at the laboratories of the University of Toronto and Toronto General Hospital.[24] Continuing Canadian research and the public health programs described



MADE IN CANADA

Products of the
SYNTHETIC DRUG COMPANY, LIMITED:

STANDARD PRODUCTS—Unlimited supply.

DIARSENOL (Salvarsan)
NEODIARSENOL (Neosalvarsan)
SODIUM DIARSENOL (Sodium Salvarsan or Salvarsan Natrium)

NEW PRODUCTS—About to be supplied.

SYNETHYL (Introduced as Luminal)
CINCHOPHEN SYNTHETIC (Introduced as Atophan)
MERCURY SALICYLATE (In gelatine capsules for intra-muscular injection)

To The Medical Profession

This Company commenced producing Diarsenol (Salvarsan) on a commercial scale early in 1915. By the end of that year they had caught up to the Canadian demand and in 1916 commenced shipping to foreign countries. Notwithstanding public statements to the contrary, there has not been a shortage of Salvarsan in Canada since 1915. Not only this, but the price is infinitely lower than the pre-war price and the quality of Diarsenol is superior in every way to any other Salvarsan produced. Later, Neosalvarsan under the name of Neodiarsenol was put on the market and has now reached the highest standard. It equals any other Neo product for solubility and freedom from toxicity and its efficiency is greater, a small dose accomplishing the same result as a larger dose of other makes.

Sodium Diarsenol, the latest and best arsenical preparation has been supplied by us for a sufficient length of time to thoroughly establish its superiority. Try it and you will be satisfied.

As a new Canadian industry for the manufacture of Synthetic Drugs, we rely confidently ask for the support of the Medical profession. Our aim is the highest standard of purity in everything we produce. Your support encourages and assists us to enter new fields of research and production.

SYNTHETIC DRUG CO. LIMITED
TORONTO CANADA

Figure 19. *The interruption of European pharmaceutical supplies in the First World War stimulated domestic manufacturing of drugs. The Synthetic Drug Company (advertising in 1920) was an Ontario manufacturer of a version of Salvarsan, the first "magic bullet" of the industry.*
(*Canadian Medical Association Journal* 10, no. 12 [December 1920]: i)

earlier, writes the historian Janice Dickin McGinnis, "put Canada at the forefront of the anti-VD campaign."[25]

The "magic bullets" that had the largest impact on clinical practice and the control of bacterial diseases were the sulpha drugs and antibiotics. The former contain the growth of bacteria and allow the body's immune system to fight the micro-organism; the latter attack the bacteria directly. In the mid 1930s, the success of sulphamidochrysoidine (later renamed Prontosil) — one of the first sulpha drugs to treat infection, developed by the German researcher Gerhard Domagk — started a stream of affordable chemical cures for some diseases. Domagk found that the orange-red dye called Prontosil was effective against the streptococcus virus in laboratory rabbits and rats. One of the first human trials was on Domagk's own daughter, who had developed septicemia (a life-threatening infection resulting from bacteria in the blood) but recovered after taking the experimental new drug.[26] Prontosil changed the history of childbirth by dramatically reducing the death rate in 1930s England from puerperal fever, a type of blood poisoning. It was also effective against gonorrhea and scarlet fever. As well, its use prevented rheumatic fever (by curing streptococcus sore throats). Domagk won the Nobel Prize in Physiology or Medicine in 1939.[27]

Bayer produced Prontosil in Germany, but almost immediately drug companies throughout the world began synthesizing their own versions of anti-bacterial compounds due to the expired patent on this drug. The success of Prontosil also encouraged researchers to look for other sulpha drugs. In 1938, a team at the British manufacturers May and Baker developed M&B 693, which worked well against pneumococci and was even more effective than sulphanilamide against streptococci.[28] Later, British and American researchers discovered other chemicals that were effective against pneumonia, a big killer of the day. Vast amounts of these new sulpha drugs were prescribed to patients. However, drug-resistant strains of bacteria soon developed, which made the "magic bullets" ineffective in some cases. This encouraged further research into developing drugs that would attack the bacteria directly — antibiotics.[29]

Penicillin, as is well known, was discovered in 1928 by Alexander Fleming, but his findings did not have clinical effect until the exigencies caused by the Second World War drove researchers at Oxford University to make penicillin a wonder drug. According to Jacalyn Duffin, "Fleming's 'discovery' that penicillum mould kills bacteria had been published earlier by others . . . . Fleming recognized the significance of his findings but did not pursue applications, nor did he cite his predecessors."[30] Instead, Howard Florey, a pathologist, and Ernst Chain, a biochemist, isolated the active ingredient. Norman Heatley, a chemist, developed the processes for making a powdered form and for testing the dosage in batches. Robert Coghill, an agricultural chemist, identified corn steep liquor as an excellent growing medium that allowed mass production.[31] The work of extracting, purifying, and producing the first batches of the drug in the small Oxford laboratory was funded mostly by the Rockefeller Foundation, an organization that was central to twentieth-century medical research. Fleming's findings lay dormant for another decade until Oxford researchers extracted, purified, and produced the drug in their small laboratory.

Penicillin's history also illustrates that the Second World War galvanized the mass production of drugs. The anticipated grievous loss of troops through infection from wounds and surgeries before the invasion of Europe in 1943 provided the impetus for the U.S. government to provide research funding to bring the drug forward for mass production in 1944.[32] Pharmaceutical companies, including Merck and Company, Charles Pfizer and Company, E. R. Squibb and Sons, and Abbott Laboratories began manufacturing penicillin for soldiers and later for the civilian market, first in the United States, then worldwide. Tetracycline and related drugs followed shortly thereafter, and synthetic penicillin was developed in the late 1950s.[33]

Penicillin greatly reduced mortality rates resulting from infected wounds, unclean surgery, and infectious diseases. It was most effective against pus-forming cocci (including pneumococcus, gonococcus, and meningococcus) and the bacilli of anthrax, tetanus, syphilis, and diphtheria. Before penicillin, approximately 30 percent of all pneumonia patients died; after the introduction of penicillin, the fatality rate dropped to around 6 percent. Pneumonia was no longer the feared disease it had been at turn of the century. In 1945, Fleming, Florey, and Chain received a Nobel Prize for their work. According to Roy Porter, the discovery of penicillin launched research in the direction of biological rather than chemical anti-bacterial agents, a direction that is being pursued vigorously in biomedical research around the world today.[34]

There are very few secondary accounts of the Canadian pharmaceutical history. (In the next chapter, we touch on the local commercial development of natural remedies.) The vast majority of commercially produced drugs and medical preparations were imported from Germany, especially before the First World War, as well as from other European countries and from the United States. The small Canadian market could offer neither the "economies of scale" nor the "economies of scope" available in Germany, where big chemical/pharmaceutical companies enjoyed efficiencies arising from the manufacture and distribution of many different

products.[35] Further, European manufacturers retained control of their drug patents, a factor that inhibited research and innovation by North American manufacturers.[36] However, the contributions to medical research and development of two pharmaceutical companies — Charles Frosst and Company and Ayerst, McKenna and Harrison — have been examined by historians.

Figure 20. *View of the effect of penicillin on a glass plate culture of* Staphylococcus aureus *at the Connaught Laboratories in Toronto, 1944. Alexander Fleming recognized the anti-bacterial function of penicillin in 1928, but its clinical potential could not be realized until the active ingredient was isolated in the 1940s.*

(Library and Archives Canada, with permission from Sanofi Pasteur Ltd. [Connaught Campus], Toronto)

Figure 21. *During the Second World War, pharmaceutical companies in several countries, including Connaught Laboratories in Toronto, rushed to manufacture penicillin for soldiers, and later for the civilian market.*

(Library and Archives Canada, with permission from Sanofi Pasteur Ltd. [Connaught Campus], Toronto)

The founder of Charles Frosst and Company was an American salesman for the Wampole Company and was responsible for their pharmaceutical sales in Canada.[37] In 1899, Frosst left Wampole and opened his own laboratory in Montreal, where he had good connections with the Department of Medicine at McGill. Before 1914, Frosst developed the widely sold painkillers 217s and 222s in his own laboratory, and tested and manufactured them in Canada with machinery of his own devising. Frosst was also determined to head a modern pharmaceutical firm. As Mel James states, "Frosst made a point of selling to licensed druggists only, avoiding those who continued to rely on old-time remedies and hypnotic compounds. This policy encouraged hospitals to deal directly with his company and they soon became his biggest customers."[38] As the firm expanded, its commitment to research increased. In 1922, they were outbid by Eli Lilly and Company for the rights to manufacture and distribute insulin in the North American market.[39] In 1923, Frosst hired Ezra Lozinski, who had trained in both medicine and pharmacology. Lozinski expanded the research and control staff from one to sixty by 1962.[40] Frosst moved into the manufacture of vitamin B2, anti-bacterials, and veterinary drugs. Today, Frosst's company is almost as famous for its annual Dingbat calendars that spoofed doctors as it is for its drugs.

The partners of Ayerst, McKenna and Harrison, a pharmaceutical company founded in 1925, began their careers at Charles Frosst, and like Frosst, they invested a share of profits in research.[41] Ayerst, McKenna and Harrison set up the first commercial biological laboratory in Canada, a two-person research laboratory in Montreal, in 1931.[42] One of its earliest research successes was the testing and standardizing of cod liver oil. Vitamins were also a major interest of this small research laboratory. Their most important contribution to Canadian research, however, was the development of Emmenin, an estrogenic hormone from the placenta that proved to be effective in correcting menstrual disorders. It was first identified and produced by J. B. Collip using large quantities of human placentas from maternity wards in Montreal. Technicians at Ayerst, McKenna and Harrison tested the strength and purity of various samples of Emmenin by injecting tiny amounts into female mice. In return for significant research investment, the company received the rights to manufacture the hormone in Canada, most of the British Empire, and eventually the United States.

Collip had wanted to patent Emmenin in the name of McGill University, but he and the university acceded to the request by Britain's Medical Research Council not to patent the hormone: the prestigious organization

was uneasy about the commercialization of science and alarmed by at least one American example of patent misuse by a university foundation.[43] The solution was to give the pharmaceutical company exclusive rights to the name "Emmenin." Coupled with Ayerst's supply of the placentas secured by its McGill connection, the "brand" advantage allowed Ayerst to set up a profitable American subsidiary.[44] A few years later, Ayerst developed Premarin, a more powerful form of natural estrogen, and its success led to a buyout of the subsidiary. Premarin became the top-selling prescription drug in North America, and Wyeth-Ayerst (Ayerst's successor) became a huge international player on its profits.[45] Alison Li argues that the Emmenin story "reflects the conflicts engendered by the growing importance of commerce to medical science."[46] Collip and other scientists came to realize that research into medicine from now on would require not only universities and medical schools, but also commercial partners.

Medical Research Expands through Public Institutions

As Michael Bliss points out, insulin's success shone a brighter light on Toronto's research environment, attracting more support, researchers, and international respect. But the groundwork had already been laid in the University of Toronto's excellent academic medical programs. As Alison Li describes, the university's medical strength began with the nineteenth-century biologist Ramsay Wright, whose graduate students of the 1880s became leaders in academic biological medicine in the United States. By the first decade of the twentieth century, it offered "one of the most progressive pre-clinical programs in North America,"[47] whose laboratory facilities were rated in the influential Flexner Report on medical education as "among the best in the continent."[48] Despite the university's reputation, it is important to realize that Canada's laboratories were necessarily sites of innovation and making-do. One of Wright's protegés was A. B. Macallum, who was one of the first researcher-teachers in North America in experimental biology, and who later developed at the University of Toronto a strong program that combined research in physiology and biochemistry. Macallum developed a number of microchemical staining techniques to identify chemical compounds at the University of Toronto. His student J. B. Collip, one of the members of the insulin team, used these techniques to examine nerve cells, about 1912. The tissue had to be frozen first and that usually meant waiting for winter, so Collip devised an apparatus that allowed all-season staining. As Alison Li describes, Collip built "an asbestos-lined box with a plate glass cover and two arm holes with padded sleeves. He used a carbon dioxide jet to chill the air inside the box and then manipulated the microtome through the sleeves."[49]

This anecdote should correct any impression that early-twentieth-century laboratory apparatus was restricted to precision equipment commercially obtained. Though the manufacture of laboratory fittings such as benches, tables, and apparatus was big business by 1900, many local laboratories completed procedures by making do with materials at hand.

Academic research was also strong in Quebec. In that province the institutionalization of physiology occurred. In 1884, British and North American scientists belonging to the British Association for the Advancement of Science met at the new physiology laboratory at McGill Medical School in Montreal.[50] William Osler considered "the integration of physiology in medicine as 'the growth of truth,' "[51] and he promoted laboratory sciences as a fundamental part of medical education at McGill University from 1880. McGill's excellence earned Rockefeller funding that built the McGill Pathological Institute and the University Clinic, both of which opened in 1924. The latter "became the world's prototype for bench-to-bedside research."[52] In brief, Montreal in the first half of the century became one of the foremost centres of medical research in North America.[53]

Medical research depends heavily on knowledge generated in other sciences. One of the great contributions of Toronto laboratory physics to medicine as well as to other sciences was the development of an electron microscope prototype in the 1930s. Ernst Ruska of Germany won the Nobel Prize in Physics in 1986 for his part in developing the electron microscope in 1931. However, the first electron microscope in North America, which was also the first practical model subsequently developed into the design sold by RCA commercially, was built at the University of Toronto McLennan Laboratories in 1938, by two physics postgraduate students, Albert Prebus and James Hillier, under the supervision of E. F. Burton.

Rather than using light, electron microscopes speed up electrons in a vacuum until their wavelength becomes much shorter than light. When a beam of these electrons is focused on biological material, the pattern of their absorption or scattering can form an image on a photographic plate. The great advantage of electron microscopes is resolution. Light microscopes cannot be used to see cell particles less than .275 microns in diameter;[54] the University of Toronto microscope provided magnification of an astounding 20,000 times actual size and resolution of 140 angstroms (the diameter of an atom is about one angstrom). However, the potential of the electron microscope for "seeing into" biological matter at the molecular and atomic level had to wait until researchers developed techniques that allowed specimens thin enough to allow electron penetration.[55]

The Role of Connaught Laboratories

The Connaught Laboratories played a major part in Canadian research before, during, and after the insulin discovery. Their history also is evidence that medical research for most of the century was generally university-based. An independent part of the University of Toronto from 1914 to 1972, the institution was founded by Dr John Gerald FitzGerald as the University of Toronto Antitoxin Laboratories.[56] FitzGerald had high aims for the laboratories. Born in Ireland and exposed to both the British public health ideals and French preventive medicine (he was a student of the Pasteur Institute), FitzGerald had a vision of a unique institution devoted to the health of the public, through medical research and the not-for-profit distribution of biological products.[57] In 1916, the laboratories acquired the Ontario Vaccine Farm, founded by Dr Alexander Stewart in 1885; the farm made smallpox vaccine for local boards of health from 1885 until 1916, from calves inoculated with the smallpox virus.[58] Under FitzGerald's direction the lab produced first rabies vaccine and later diphtheria antitoxin that was distributed freely. Renamed the Connaught Laboratories in 1917, it also produced high-quality serums and vaccines against tetanus, meningitis, and influenza. However, before the First World War, American firms were supplying most of the smallpox vaccine for Ontario.

In the 1930s, the Connaught Laboratories were instrumental in the development of heparin, another example of institutional co-operation between university physiology departments, hospitals, and teams of researchers.[59] Dr Charles Best as head of the University of Toronto's Physiology Department formed a team to investigate how to make clinical use of heparin, discovered in 1916. Heparin is a blood anticoagulant, used in major surgery to prevent the formation of blood clots (thrombosis) that can stop the flow of blood to the lungs, a potentially fatal development. However, no one had yet been able to make heparin safe for humans; made from dog liver, it was also expensive and so far only available in small quantities. The organic chemist Arthur F. Charles and the biochemist David A. Scott, who had worked on the development of insulin,[60] discovered that the extract could be derived from decomposing beef intestines and lungs. They conducted their work at a rural property owned by the Connaught Laboratories, where the odour of spoiling organs did not trouble the neighbours. By 1936, Charles and Scott had developed a pure dry form of heparin that could be administered in a salt solution.[61]

Meanwhile, Dr Gordon Murray was experimenting on animals with the new form of heparin, with promising results. He first used heparin on patients in May 1935. His great surgical skills, combined with the purified heparin's ability to prevent blood coagulation, meant a significant broadening of the range of operations that could be attempted for life-saving and palliative surgery.[62] Murray would go on to develop one of the first artificial kidneys (see chapter 7); he was able to use the artificial kidney on humans only because heparin allowed the blood to circulate through the machine without coagulation.

As Christopher Rutty states, "Heparin thus became Connaught's second product, after insulin, to be recognized as an international biological standard."[63] Connaught Laboratories also made an important contribution to the development and manufacture of the Salk vaccine for polio in the 1950s, as described in chapter 6. Heparin was patented in 1949, but because it could be produced more cheaply elsewhere, Connaught stopped producing it in the 1950s. Connaught scientists also developed a purification process for penicillin.[64] Another important Connaught contribution before the mid-century was pertussis vaccine, and the laboratories made dried blood serum (used to prevent shock) and penicillin for the use of soldiers overseas. The laboratory also developed "combined antigens that provided protection against diphtheria, pertussis and tetanus in one shot."[65] Besides these specific contributions, Connaught Laboratories developed mediums for the culture of viruses and helped to shape the emerging fields of nutrition, parasitology, and even administration.[66] These important contributions came out of funds generated by the sale of insulin.

The National Research Council and Montreal Neurological Institute

As the development of insulin and heparin suggests, during the interwar period in Canada serious experimental work in medicine took place exclusively in research centres affiliated with, or part of, universities. Well-equipped laboratories were only to be found in academic settings, and departments were allocated money for research from general university funds. In the late 1930s, the Canadian government cemented this pattern through the activities of the National Research Council.

The National Research Council (NRC) is a government organization that supports basic and applied research in science and technology.[67] Although new laboratories were built in Ottawa in the early 1930s, the NRC adopted a predominantly extramural system of funding medical research carried out in existing university facilities. Alison Li argues that the National Research Council did not have much choice but to support an extramural program because of financial constraints and the availability of personnel.[68] There was not a critical mass of medical researchers, and they were widely dispersed,

Figure 22. *Worker adjusts a valve in front of a centrifuge used during penicillin manufacture at the Connaught Laboratories in Toronto, 1944.*

(Library and Archives Canada, with permission from Sanofi Pasteur Ltd. [Connaught Campus], Toronto)

as described by Sir Frederick Banting in his 1939 survey of medical research centres in Canada.[69] (In comparison, Britain and the United States supported mixed extramural and intramural systems. These governments provided funds for research at medical schools and universities and also created central laboratories, at the National Institute of Medical Research at Mill Hill and the National Institutes of Health in Bethesda, Maryland, respectively.) The Associate Committee on Medical Research of the National Research Council of Canada, chaired by Banting, was established in 1938. Eight years later it became the Division of Medical Research, chaired by James B. Collip. Finally, in 1960, it was made independent of the National Research Council and renamed the Medical Research Council. In its various forms, the Medical Research Council co-ordinated and provided funding for experimental work, stimulating and institutionalizing medical research in Canada.[70]

Besides the NRC funding model, another major factor made medical research in Canada dependent on universities. Unlike the situation in the United States, there were no large domestic philanthropic foundations willing or able to provide the level of support required. Katherine McCuaig lists economic and broader cultural differences in the two countries to explain this phenomenon:

> *Despite the prominent example of American foundations — the Rockefeller, Carnegie, and Russell Sage foundations — funded with gilded-age fortunes, interwar Canada never saw the development of native-born equivalents: individual Canadians using their personal fortunes to establish independent philanthropies. The American examples may have been due to a unique and peculiar set of circumstances — economic, industrial, religious, and political — existing in late nineteenth-century America that permitted the acquisition of vast wealth, yet infused society and the new industrialist with a complex mix of progressive ideology supporting scientific management and the social gospel.*[71]

She also points out that Canadian industrialists preferred to fund specific causes rather than open-ended research. For example, Adam Beck, a prosperous manufacturer in London, Ontario, and chair of the Hydro-Electric Power Commission of Ontario, was pivotal in the development of the National Sanatorium Association.[72] Albert Gooderham, of Gooderham and Worts distillery and chairman of the Ontario Red Cross, assisted James FitzGerald by buying the Dufferin Farm for Connaught Laboratories.

The Rockefeller Foundation, however, played a pivotal role in one of the Canadian success stories in medical research.[73] In 1934, Wilder Penfield founded the Montreal Neurological Institute, hoping to build "a completely Canadian institution"[74] that would bring together "neurology, neurosurgery, neuropathology, and neurophysiology."[75] He and his associate William Cone opened Canada's first neurocytology laboratory in Montreal in 1928, brought to McGill's Royal Victoria Hospital by surgeon Edward Archibald, who pioneered Canadian neurosurgery.[76] The pivotal moment was winning the support of the Rockefeller Foundation, though about 40 percent of the initial funding came from the Quebec and Montreal governments.[77] The contributions of the great Canadian-born physician William Osler indirectly led to the founding of the Montreal Neurological Institute. According to the neurologist Harvey Cushing, it was "the incomparable [William] Osler's . . . textbook that aroused the interest of Mr. Rockefeller in Medicine and led to the establishment of the foundation bearing his name."[78]

In the early decades of the twentieth century, technology had not benefited neurology as it had other specialties, despite the many attempts of Harvey Cushing and other neurologists to develop diagnostic and therapeutic instruments and procedures for surgery in the brain and spine. As Edward Shorter points out, the techniques for localizing problems in the brain were not developed until the late nineteenth century, and surgery was not practical in the tightly packed cranium without knowing what one was going after.[79] Cushing, working with the physicist W. T. Bovie and electrical technicians, devised mechanical and electrical procedures and instruments that helped to remove foreign objects and damaged matter and, above all, to control bleeding during cranial surgery.[80] But the electrical devices were dangerous to doctors and patients, despite Cushing's adaptations.[81] Still, in the words of one historian, "most of the neurologic instruments and diagnostic techniques developed in the United States in the 19th century were either simple gadgets, very cumbersome appliances that could readily be substituted by less complex techniques with little loss of clinically useful information, or relatively trivial modifications of previously developed instruments."[82]

In that context, the contributions of the Montreal Neurological Institute (MNI) were huge. Penfield and his colleagues built a research institution that, over more than three decades, taught the world about the brain, and particularly about epilepsy, neurosurgery, neurochemistry, and neurocytology. Through many brain operations, Penfield undertook to learn what parts of the brain were related to what functions. In what became known as the "Montreal Procedure,"

he employed exemplary scientific method and the participation of the patient. He rigged an overhead mirror to permit a photographic record of the surgical excisions (of scarring and lobes) and the cortical mapping he accomplished during the surgeries.[83] In particular, he was able to localize speech, sensation, emotional deficit, and memory, by electrically stimulating the cortex and observing the results on the conscious — locally anaesthetized — patients.

As William Feindel points out, the participation of the conscious patient was essential in this research. Learning the precise centres of this kind of high functioning was impossible using only animal research. Penfield's "Montreal Procedure" not only expanded the knowledge of the brain and its pathology, and the international profile of the MNI, but helped many thousands of seizure-suffering individuals who underwent the surgery. The procedure also reduced the risk of memory impairment sometimes caused during surgery to remove epileptogenic tissues.[84]

A number of MNI medical researchers were part of Penfield's operating team and published in related fields. The psychologist Donald Hebb carried out detailed psychological assessments of patients before and after surgery. He used this work to formulate his theory of neural structures and feedback loops. As a website celebrating Canadian science explains, "The cell-assembly theory guided Hebb's landmark experiments on the influence of early environment on adult intelligence and foreshadowed neural network theory, an active line of research in artificial intelligence."[85] William Cone functioned as chief neurosurgeon at the MNI. As part of the many neurosurgical methodologies he developed, Cone designed air-driven tools (as well as special apparatus for spinal traction).[86] Herbert Henry Jasper is now recognized as "one of the world's leading neurophysiologists" for his writings and work with Penfield.[87] In 1935, he conducted the first electroencephalograph (EEG) in the United States. From 1938, at the MNI, he pioneered electroencephalography for epileptic patients with localized brain seizures.[88] Jasper was awarded the Albert Einstein World Award for Science by the World Cultural Council in 1996.

Under Penfield, the Montreal Neurological Institute accumulated a long list of accomplishments and discoveries. These included understanding the role of the amygdala and hippocampus in memory as well as contributions to neuroradiology by Arthur Elvidge, who pioneered "visualization of the cerebral blood vessels by X-ray angiography in the 1930s."[89] In the 1940s, C. Miller Fisher made an important contribution to the understanding of strokes. His major finding, that the carotid artery and not the heart was the source of many emboli, involved creative research, as Charles Roland describes:

> *The relationship between the carotid artery and emboli was difficult to prove because at this time autopsies did not allow dissection of the neck for cosmetic reasons. By private arrangements with funeral homes, he explored this artery and to his amazement he found a rough calcified nodule covered with thrombus (blood clot) where the artery divides — an obvious source of emboli of all sizes . . . . Thus was born the concept that the carotid artery was indeed the chief offender in strokes and surgeons quickly responded by opening the artery and carefully removing the offending plaque.*[90]

Throughout the twentieth century, the MNI remained one of the leading medical centres for the clinical and scientific study of brain disorders.

Conclusion

Between 1900 and 1950, a number of new and effective drugs were made available to doctors and patients, including insulin, penicillin, and various vaccines and antitoxins. Insulin was the great Canadian breakthrough and it had an immediate impact in the medical world, not as a "cure" for diabetes but as a therapy that saved lives and managed the disease. Moreover, the discovery of insulin illuminates the broader context of the underlying structures that supported medical research in Canada. For example, Connaught Laboratories, developed from the public health vision of its founder, John FitzGerald, provided antitoxins, insulin, and later heparin. An entity of the University of Toronto, Connaught Laboratories and its contributions illustrates how medical research in Canada was largely conducted in university-based and governmental institutional settings with public funding. This was in contrast to the United States, where philanthropic foundations were key supporters of medical research. A Canadian exception to this was the Montreal Neurological Institute under Wilder Penfield, which was funded by the Rockefeller Foundation.

Beginning with insulin, the pharmaceutical industry in Canada, the United States, and Europe collaborated and later competed in the medical marketplace. The Eli Lilly pharmaceutical company in Indianapolis made large-scale production of insulin possible. In agreement with Connaught Laboratories, Lilly received a head start in the U.S. market, while Connaught distributed in the Canadian market and the Medical Research Council in Great Britain supplied insulin in that country. Other manufacturers were licensed

over the next several years. This association between the university, local laboratories, giant pharmaceutical companies, and overseas government institutions became a typical set of relationships struck to bring new drugs to the market.

The greatest new drug of this period, and probably of the twentieth century, was penicillin. Early sulpha drugs such as Prontosil, developed by Gerhard Domagk in Germany, proved effective against streptococci and puerperal fever, significantly dropping maternal mortality rates. But penicillin proved even more effective in combatting infection because it erased all traces of the infection. In the 1940s, pharmaceutical companies manufactured enough penicillin for soldiers, and later mass-produced the drug for civilians. Penicillin reduced infection arising from wounds and surgeries and also reduced mortality rates from one of the leading causes of death — pneumonia. American pharmaceutical companies were the first to manufacture penicillin, but Canadians took part in its large-scale production.[91] The discoverers of insulin, sulphamidochrysoidine (renamed Prontosil), and penicillin all received Nobel Prizes, attesting to society's recognition of the impact of these drugs in combatting disease.

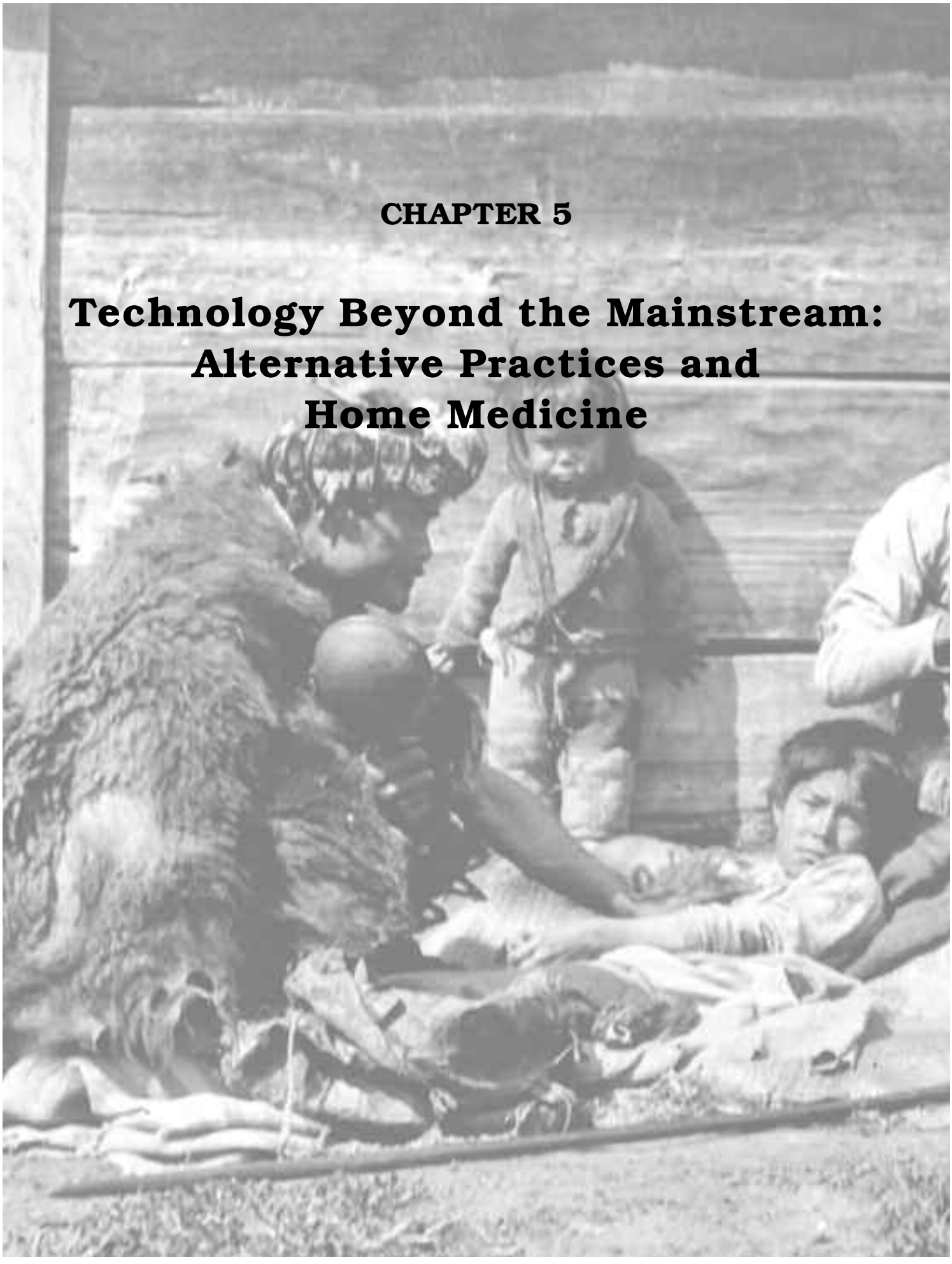
Despite society's hope and optimism in the delivery of more "wonder drugs" after penicillin, researchers have not developed effective drugs to cure AIDS, cancer, or other fatal twentieth-century diseases. Nevertheless, drug therapy increased in the era after the Second World War. The pharmaceutical industry expanded and evolved into a powerful actor in the medical marketplace by delivering and marketing drugs to treat or manage a variety of other medical conditions, including depression, mental illness, infertility, impotence, heart disease, attention deficit disorders, and more. Drugs became sought-after curative therapies as well as big business by the last quarter of the twentieth century.

Notes

1. This section is heavily paraphrased from Michael Bliss, *The Discovery of Insulin* (Toronto: McClelland & Stewart, 1982), which historians consider the definitive account on the history of the discovery of insulin. Bliss's book has been translated into French, Japanese, and Greek and published in multiple English editions, including a reprinted 25th anniversary edition in 2007.
2. Chris Feudtner, *Bittersweet: Diabetes, Insulin, and the Transformation of Illness* (Chapel Hill: University of North Carolina Press, 2003), 5.
3. Bliss, *Discovery of Insulin*, 23–8; Feudtner, *Bittersweet*, 4–6; Jacalyn Duffin, *History of Medicine: A Scandalously Short Introduction* (Toronto: University of Toronto Press, 1999), 104.
4. Bliss, *Discovery of Insulin*, 23–4.
5. For additional information on Joslin, see Anna Carr Holt, *Elliott Proctor Joslin: A Memoir* (Worcester, Mass.: ASA Bartlett Press, 1969); Donald M. Barnett, *Elliott P. Joslin, M.D.: A Centennial Portrait* (Boston: Joslin Diabetes Center, 1998).
6. Bliss, *Discovery of Insulin*, 49–50.
7. Ibid., 58.
8. Ibid., 59.
9. Ibid., chap. 3, 51–83.
10. For more on Collip and his role, see Alison Li, *J. B. Collip and the Development of Medical Research in Canada: Extracts and Enterprise* (Montreal: McGill–Queen's University Press, 2003); Michael Bliss, "J. B. Collip: A Forgotten Member of the Insulin Team," in *Essays in the History of Canadian Medicine*, ed. W. Mitchinson and J. D. McGinnis (Toronto: McClelland & Stewart, 1988), 110–25.
11. Bliss, "Introduction: The Discovery of Insulin," in *The Discovery of Insulin at the University of Toronto: An Exhibition Celebrating the 75th Anniversary*, by Katharine Martyn (Toronto: Thomas Fisher Rare Book Library, University of Toronto, 1996), 28–9.
12. Ibid., 30.
13. Ibid., 31.
14. Elizabeth Hughes Letters, 1922, Thomas Fisher Rare Book Library, University of Toronto, quoted in Bliss, "Introduction: The Discovery of Insulin," 31–2.
15. See Michael Bliss, *Banting: A Biography* (Toronto: University of Toronto Press, 1984); also by Bliss, "Rewriting Medical History: Charles Best and the Banting and Best Myth," *Journal of the History of Medicine and Allied Sciences* 48 (1993): 253–74.
16. Bliss, *Discovery of Insulin*, 129.
17. Jordan Goodman, "Pharmaceutical Industry," in *Medicine in the Twentieth Century*, ed. Roger Cooter and John Pickstone (Amsterdam: Harwood Academe Publishers, 2000), 145.
18. Feudtner, *Bittersweet*, 102.
19. The following description of the development of the pharmaceutical industry is based on Goodman, "Pharmaceutical Industry," 141–54.
20. Elizabeth A. Iles, *Ask the Grey Sisters: Sault Ste. Marie and the General Hospital, 1898–1998* (Toronto: Dundurn Press, 1998), 59–60.
21. Roy Porter, *The Greatest Benefit to Mankind: A Medical History of Humanity* (New York: W. W. Norton & Co., 1997), 448.
22. Duffin, *History of Medicine*, 103. See also John Mann, *Elusive Magic Bullet: The Search for the Perfect Drug* (New York: Oxford University Press, 1999).
23. Roy Porter, "The Rise and Fall of the Age of Miracles," *History Today* 46 (November 1996): 70; the historian Jacalyn Duffin notes that Paul Ehrlich developed an earlier "magic bullet" — the dye trypan red, for experimental trypanosomiasis, in 1903. Duffin, *History of Medicine*, 103.
24. "The Manufacture of Salvarsan in Canada," *CMAJ* 5, no. 2 (February 1915): 124–6.
25. Janice Dickin McGinnis, "From Salvarsan to Penicillin: Medical Science and VD Control in Canada," in *Essays in the History of Canadian Medicine*, 128.
26. Duffin, *History of Medicine*, 103.
27. See David M. Kiefer, "Miracle Medicines: The Advent of the Sulpha Drugs in the Mid-1930s Gave Physicians a Powerful Weapon," *Today's Chemist at Work* 10, no. 6 (June 2001): 59–60, available online at http://pubs.acs.org/journals/tcwoe7/about.html (accessed March 10, 2004); Porter, *Greatest Benefit to Mankind*, 453–4.

28. Roy Porter, *Blood and Guts: A Short History of Medicine* (New York: W. W. Norton, 2002), 104, and *Greatest Benefit to Mankind*, 453–4.
29. Porter, *Greatest Benefit to Mankind*, 454.
30. Duffin, *History of Medicine*, 103.
31. Porter, *Greatest Benefit to Mankind*, 456–7; Duffin, *History of Medicine*, 103–4. For an overview of deep culture fermentation, *Encyclopedia Britannica*, s.v. "Pharmaceutical industry," *Encyclopedia Britannica Online* (2005), http://search.eb.com/eb/article?tocId=82323 (accessed April 18, 2005).
32. Ruth Schwartz Cowan, *A Social History of American Technology* (Oxford: Oxford University Press, 1997), 310–8.
33. For recent histories of the discovery and production of penicillin, see Robert Bud, *Penicillin: Triumph and Tragedy* (Oxford: Oxford University Press, 2007); Scott H. Podolsky, *Pneumonia Before Antibiotics: Therapeutic Evolution and Evaluation in Twentieth-Century America* (Baltimore: Johns Hopkins University Press, 2006); John E. Lesch, ed., *The First Miracle Drugs: How the Sulpha Drugs Transformed Medicine* (Oxford: Oxford University Press, 2006).
34. See Porter, *Greatest Benefit to Mankind*, "Antibiotics and the Drugs Revolution," 454–60.
35. Goodman, "Pharmaceutical Industry," 142. "Economies of scale" refers to "shared common knowledges and practices" whereby "firms could economize on their inputs in research, development, production, standardization, and even testing procedures."
36. See Jonathan Liebenau, *Medical Science and Medical Industry, 1890–1929: The Formation of the American Pharmaceutical Industry* (London: Basingstoke/Macmillan, 1987), chap. 7.
37. This account is a synopsis of Mel James, "Charles Edward Frosst: Pioneer of Medical Preparations," Government of Canada, Canada Heirloom Series, vol. 5, Canadian Achievers, http://collections.ic.gc.ca/heirloom_series/volume5/212-215.htm (accessed March 16, 2003).
38. James, "Charles Edward Frosst."
39. Li, *Collip*, 72.
40. E. Gordon Young, *The Development of Biochemistry in Canada* (Toronto: University of Toronto Press, 1976), 51–2.
41. The following paragraph relies completely on Li, *Collip*, 72–4, 84–7.
42. Young, *Development of Biochemistry in Canada*, 5.
43. This is the Wisconsin Alumni Research Foundation's abuse of the vitamin D patent to promote the local dairy industry, in 1925. Li, *Collip*, 78–9.
44. Li, *Collip*, 86.
45. Ibid., 87.
46. Ibid., 88.
47. In the opinion of Sandra McRae, cited in Li, *Collip*, 7.
48. Cited in Li, *Collip*, 7, on which this paragraph relies.
49. Li, *Collip*, 9–10.
50. W. Bruce Fye, *The Development of American Physiology: Scientific Medicine in the Nineteenth Century* (Baltimore: Johns Hopkins University Press, 1987), 177; for biological sciences in medical education at McGill University, see Joseph Hanaway, Richard Cruess, and James Darragh, *McGill Medicine*, vol. 2, *1885–1936* (Montreal: McGill–Queen's University Press, 2006), 135–50. See also Gerald L. Geison, ed., *Physiology in the American Context, 1850–1940I* (Bethesda, Md.: American Physiological Society, 1987).
51. Duffin, *History of Medicine*, 56.
52. N. Tait McPhedran, "Canadian Medical Schools Before ACMC," *CMAJ* 148, no. 9 (May 1993): 1536; there were medical schools founded in Edmonton in 1913, Saskatoon in 1926, and Winnipeg in 1883, all eventually university-affiliated, but they were small, and their commitment to laboratory training and research varied, partly according to funding. Ibid., 1533–7. In 1909, even Halifax's Medical College was singled out as having a "single utterly wretched laboratory" by Abraham Flexner, *Medical Education in the United States and Canada (circa 1910; repr., New York: Arno Press, 1972), 321*. See also N. Tait McPhedran, *Canadian Medical Schools: Two Centuries of Medical History, 1822 to 1922* (Montreal: Harvest House, 1993).
53. Hanaway, Cruess, and Darragh, *McGill Medicine*, vol. 2.
54. John H. L. Watson, "The Electron Microscope: Travelling the Unknown World of Inner Space," http://collections.ic.gc.ca/heirloom_series/volume4/258-261.htm (accessed May 15, 2004).
55. For a detailed description of the microscope and its development, see John H. L. Watson, "Very Early Electron Microscopy in the Department of Physics, the University of Toronto: A Personal Recollection," www2.physics.utoronto.ca/overview/history/microsco/microscopy.htm (accessed February 8, 2008). See also Nicolas Rasmussen, *Picture Control: The Electron Microscope and the Transformation of Biology in America, 1940–1960* (Stanford, Conn.: Stanford University Press, 1997).
56. See Paul Bator and A. J. Rhodes, *Within Reach of Everyone: A History of the University of Toronto School of Hygiene and the Connaught Laboratories*, vol. 1, *1927 to 1955* (Ottawa: Canadian Public Health Association, 1990). The FitzGerald contribution is detailed in Christopher Rutty, "Connaught and the Defeat of Diphtheria," *Contact* 9, no. 1 (February 1996), www.healthheritageresearch.com/Diphtheria-conn9602.html (accessed March 15, 2004); Richard Levick, "John G. FitzGerald, 1882–1940: Canada's Public Health Visionary," Government of Canada, Canada Heirloom Series, vol. 5, Canadian Achievers, http://collections.ic.gc.ca/heirloom_series/volume5/90-95.htm (accessed March 16, 2003); and James FitzGerald, "James FitzGerald: Troubled Healer," reprinted from *The Medical Post* in *Future Health* (Winter 2000), www.chrcrm.org/fh_winter00_healer.htm (accessed March 9, 2004).
57. Christopher J. Rutty, "Dr. Robert Davies Defries (1889–1975): Canada's 'Mr Public Health,' " originally published in Lois N. Magner, ed., *Doctors, Nurses and Practitioners* (Westport, Conn.: Greenwood Press, 1997), 62–69, www.healthheritageresearch.com/Defries-biopaper.html (accessed March 10, 2004).
58. W. B. Spaulding, "The Ontario Vaccine Farm, 1885–1916," *CBMH* 6, no. 1 (1989): 45–56.
59. The following is derived primarily from Christopher J. Rutty, "Miracle Blood Lubricant: Connaught and the Story of Heparin, 1928–1937," *Contact* 9, no. 4 (August 1996), www.healthheritageresearch.com/Heparin-Contact9608.html#Aventis%20Pasteur%20Ltd.%20new%20name (accessed March 10, 2004).
60. Young, *Development of Biochemistry in Canada*, 53.
61. For more on the story of heparin, see W. G. Bigelow, *Mysterious Heparin: The Key to Open Heart Surgery* (Toronto: McGraw-Hill Ryerson, 1990); James A. Marcum, "The Development of Heparin in Toronto," *Journal of the History of Medicine and Allied Sciences* 52 (July 1992): 310–37; James A. Marcum, "The Origin of the Dispute over the Discovery of Heparin," *Journal of the History of Medicine and Allied Sciences* 55 (2000): 37–66; Ronald J. Baird, "Give Us the Tools — The Story of Heparin as Told by Sketches from the Lives of William Howell, Jay McLean, Charles Best and Gordon Murray," *Journal of Vascular Surgery* (January 1990): 4–18.

62. Shelley McKellar, *Surgical Limits: The Life of Gordon Murray* (Toronto: University of Toronto Press, 2003), 38–51.
63. Rutty, "Miracle Blood Lubricant."
64. Paul A. Bator, *Within Reach of Everyone: A History of the University of Toronto School of Hygiene and Connaught Laboratories Limited*, vol. 2, *1955 to 1975* (Ottawa: Canadian Public Health Association, 1995), 105.
65. "Aventis Pasteur in Canada: A Short History," www.aventispasteur.ca/Index.cfm?FA=ca_history_intro (accessed March 16, 2004).
66. Bator, *Within Reach of Everyone*, 105.
67. NRC researchers working out of the NRC laboratories were often collaborating with university researchers. Key NRC accomplishments during this period included the invention of the pacemaker (1940s), the development of canola (1940s), and the design of the Crash Position Indicator (1950s) and the cesium beam atomic clock (1960s). See www.nrc-cnrc.gc.ca/aboutUs/facts_history_e.html (accessed November 13, 2007).
68. Alison Li, "Expansion and Consolidation: The Associate Committee and the Division of Medical Research of the NRC, 1938–1959," in *Building Canadian Science: The Role of the National Research Council*, ed. Richard A. Jarrell and Yves Gingras, special issue, *Scientia Canadensis* 15 (1991): 89–103.
69. National Research Council of Canada, Division of Medical Research RG 77, series A-1, vol. 279, files 40-1-1 and 2, Library and Archives Canada; Ontario Ministry of Health, files RG 10-6-0-1529 and 1530, Medical Research Projects in Canada, Archives of Ontario.
70. Li, "Expansion and Consolidation," 89–103.
71. Katherine McCuaig, *The Weariness, the Fever and the Fret: The Campaign Against Tuberculosis in Canada, 1900–1950* (Montreal: McGill–Queen's University Press, 1999), 119.
72. McCuaig, *Weariness, Fever, Fret*, 119.
73. In 1919, Rockefeller funding (in the amount of $5 million) to medical schools in Toronto, Montreal, and Halifax contributed to significant changes in Canadian medical education. For this story, see Marianne P. Fedunkiw, *Rockefeller Foundation Funding and Medical Education in Toronto, Montreal and Halifax* (Montreal: McGill–Queen's University Press, 2005).
74. William Feindel, "The Contributions of Wilder Penfield and the Montreal Neurological Institute to Canadian Neurosciences," in *Health, Disease and Medicine: Essays in Canadian History*, ed. Charles G. Roland (Toronto: Clarke Irwin for the Hannah Institute for the History of Medicine, 1984), 347–58.
75. Ibid., 349.
76. William Feindel, "Neurosurgery at the Montreal Neurological Institute and McGill University Hospitals," *Neurosurgery* 39, no. 4 (October 1996): 830.
77. Li, *Collip*, 114.
78. Harvey Cushing, "Surgery of the Head," in *Surgery: Its Principles and Practice* (1908), ed. W. W. Keen, vol. 3, 17–276, cited in Feindel, "Neurosurgery at the MNI," 833.
79. Edward Shorter, *Health Century* (New York: Doubleday, 1987), 104.
80. On artery forceps and Cushing clips, glass tubes and electromagnets, see "Electro-Surgery as an Aid to the Removal of Intracranial Tumors," *Surgery, Gynecology and Obstetrics* 47 (December 1928): 751–84, reprinted in Joel Howell, ed., *Technology and American Medical Practice, 1880–1930: An Anthology of Sources* (New York: Garland, 1988), 132. See also Michael Bliss, *Harvey Cushing: A Life in Surgery* (Oxford: Oxford University Press, 2005).
81. Harold Ellis, *A History of Surgery* (London: Greenwich Medical Media, 2001), 143.
82. Douglas J. Lanska, "The Role of Technology in Neurologic Specialization in America," *Neurology* 48 (1997): 1726.
83. Penfield imported microscopic and brain mapping techniques from Spain and Germany and built on them. See Thomas Morley, *Kenneth George McKenzie and the Founding of Neurosurgery in Canada* (Markham, Ont.: Fitzhenry & Whiteside, 2004).
84. Feindel, "Neurosurgery at the MNI," 831.
85. "Donald O. Hebb," Science.ca, www.science.ca/scientists/scientistprofile.php?pID=170 (accessed May 15, 2004).
86. Feindel, "Neurosurgery at the MNI," 832.
87. "Herbert Henry Jasper," Science.ca, www.science.ca/ (accessed May 15, 2004).
88. Feindel, "Neurosurgery at the MNI," 833.
89. Feindel, "Contributions of Wilder Penfield," 351.
90. Charles Roland, "C. Miller Fisher: Neurologist Preventing Strokes," Government of Canada, Canada Heirloom Series, vol. 5, Canadian Achievers, http://collections.ic.gc.ca/heirloom_series/volume5/210-211.htm (accessed March 16, 2003).
91. Terrie M. Romano, "The Associate Committees on Medical Research of the National Research Council and the Second World War," *Scientia Canadensis* 15, no. 2 (1991): 82.



CHAPTER 5

Technology Beyond the Mainstream: Alternative Practices and Home Medicine

Technology Beyond the Mainstream: Alternative Practices and Home Medicine

Doctors in the late nineteenth century who were trained in regular medical schools faced competition from a number of medical sects and from traditional healers. Orthodox medicine[1] did gain prestige and power through the first half of the twentieth century: antiseptic surgery and decreasing mortality rates, the scientific laboratory and its equipment, and finally the "magic bullets" of the sulpha drugs and penicillin massively reinforced its authority. However, regular medicine never succeeded in completely stamping out other forms of healing, each of which had its own technology consisting of material aids and knowledge-based procedures. This chapter addresses four of many alternative[2] approaches to health and disease that differed from mainstream medicine — chiropractic medicine, unorthodox cancer treatments, aboriginal medicine, and home medicine.[3]

Practitioners of unorthodox and traditional medicine often claim that their techniques and regimes are more natural and holistic than those of regular medicine, that they rely less on intervention through technological devices, appliances, and drugs.[4] However, the history of chiropractic medicine illustrates that the attempt to create a simpler, more patient-centred approach does not preclude a complicated and ambivalent relationship to medical technology.

Other commonalities show that alternative and regular medical practices were not discrete streams. They shared patients, and they often shared healers: the existence of unorthodox treatments developed by conventionally trained practitioners illustrates this overlap. Unconventional treatments flourished where regular medicine was either ineffective or harsh. The examples discussed here are cancer treatments that thrived in Ontario between the wars and "toe-twisting" treatments for arthritis.

Also outside the medical mainstream were traditional medicine and home care. Canada's regional and cultural diversity has fostered distinct forms of medicine that, in their period and place, were dominant rather than alternative. Aboriginal medicine and healing technology will be briefly described as an example of traditional medicine. Home medicine was the only medicine available in much of Newfoundland and in other parts of rural Canada in the early twentieth century. Even in cities, the home was the place where babies were born and the very ill were accommodated until the development of the modern technology-centred hospital of the 1920s. Like chiropractic medicine and unorthodox treatments for chronic disease, aboriginal and home medicine had their own technologies, which drew on and responded to twentieth-century developments in orthodox medicine.

Chiropractic Medicine: An Alternative System

Orthodox medicine claims ownership of a body of knowledge that it disseminates at professional schools. The regular profession has control over entry and discipline and, until the late twentieth century, has strongly favoured middle-class males as candidates. It enjoys privileged access to hospitals, hospital technology, and drug prescribing. Its practitioners enjoy state support; their monopoly on various types of medical services has been protected by provincial licensing in Canada and fostered through public funding of services. Chiropractic medicine is an example of an alternative system or school of medicine, whose practitioners belonged to self-defined organizations, attended schools, and published their own journals — but received no or limited state support in the first half of the twentieth century. Besides chiropractic, healers and patrons of homeopathy, osteopathy, hydropathy, Christian Science, and naturopathy could all be found in Canada before 1950, but chiropractic was the most successful of these in gaining official licensing, access to hospitals and laboratories, and funding.[5]

A major thread in the history of chiropractic in the first half of the century is its internal struggle over technology, a tension that goes to the heart of alternative medicine's claims to be more natural than conventional medicine. In regular medicine, as we have seen, the clinical bedside examination had been bolstered and often superseded by laboratory tests and the use of diagnostic machines. Conversely, unorthodox healers, including chiropractors, were at first proud to distinguish themselves by pointing to their refusal to use instruments and apparatus, and particularly drugs.

A much-vaunted antipathy to drugs and technology was a core message of its charismatic founder, D. D. Palmer, 1845–1913. Palmer was born in a small village in what is now Pickering Township, Ontario. After brief careers in shoemaking, teaching, farming, and beekeeping, he set up practice as a magnetic healer in Davenport, Iowa.[6] Medicine, conventional and unorthodox,

has strong links to this old tradition. Beginning with the eighteenth-century Mesmerists, magnetic healers believed that the movement of their hands on and over the body could rechannel the "vital forces" and heal many kinds of painful ailments.[7] However, by the late nineteenth century when Palmer took up its practice, magnetic healing was waning in credibility and popularity. In 1895, Palmer began to explore what became chiropractic after he was able to cure his janitor Harvey Lillard's chronic deafness by manipulating his thoracic spine in one cracking adjustment. Palmer chose the word *chiropractic* for his new practice, a term that signified "done by hand." Two years later, he opened his school of chiropractic.

The historian James Whorton considers that a principle of most alternative medicine is that "effective therapeutic procedures can be developed purely through empirical trials without the guidance of sophisticated scientific theory."[8] D. D. Palmer and his early followers were not interested initially in developing an explanation for why manipulation of the spine was effective. However, theorizing soon began, probably in imitation of scientific medicine's search for rationales. According to Palmer, most ailments resulted from improper "nerve tension," itself caused by "subluxation" or impinging of the nerve by spinal or other skeletal contact. Nerves could therefore be injured by accident or trauma to the skeleton. But chiropractic theory also included a wide range of environmental, physical, and moral predisposing and primary causes of disease. For instance, alcohol and smoking and other poisonous irritations could also force vertebrae out of position. Further, Palmer taught that the effects of the subluxation or nerve damage could be experienced in organ systems distant from the local trauma. In combining a broad spectrum of causal factors with a narrow focus on one bodily system (the nerves), chiropractic resembled osteopathy, the other major alternative system of the first half of the century.[9]

The main tools of the chiropractor were his or her hands, laid on the patient with greater or lesser force to cause adjustment of the spine. The practitioner often used a special table, the first patented in 1909, and a more complicated "contemporary flexion-distraction table" invented by James Cox. Palmer's grand claims for his simple technique soon moved beyond the restoration of individual health to the moral and spiritual correction of society. Yet chiropractic therapy was humble in a manner that eluded orthodox medicine. It was not proposed as stand-alone healing, but as the method by which blockages to the natural healing systems of the body were removed. The chiropractic doctor professed to work with the body, in a natural and mild way, to promote nature's own healing.

Like other early-twentieth-century alternative systems, chiropractic equated natural healing with drugless healing. This was a relief to the many critics (and victims) of regular medicine's excessive use of depletive medicines, especially calomel. For chiropractic, medically authorized drugs were in the same category as alcohol, that is, as pollutants of the body and the soul.[10] Palmer's teaching did include botanical and herbal preparations, as critics were quick to point out, but chiropractors argued that they provided only natural remedies, completely different from the dangerous and arrogant interventions of regular medicine.

The history of chiropractic schools, in Canada and elsewhere, shows that the system's relationship to regular medical science and technology caused dissension inside and criticism outside the sect. Palmer founded his school of chiropractic in Davenport, in 1897, attracting working-class men and women as healers as well as patients. By 1920, there were nearly two dozen schools in the United States. An American-trained chiropractor may have been practising in Ontario as early as 1902.[11] The first school in Ontario opened in 1909 in Sault Ste Marie but was short-lived, as was a second school that opened in Hamilton, Ontario, in 1914. No doubt their success was compromised by the competition provided by the fount of chiropractic wisdom in nearby Ohio. By 1920, the Palmer School of Chiropractic had almost three thousand students, more than any school of any system of healing in the world, and trained three-quarters of all those in practice.[12]

But the failure of the Canadian Chiropractic College in Hamilton also stemmed from its rejection of basic sciences and technology, and the medical and official criticism of "bony heretics" that ensued.[13] In 1917, the Hodgins Commission on Medical Education in Ontario called on chiropractors to describe their theories and practice. At the time, chiropractic and other physical therapies such as physiotherapy were enjoying a new prestige (and therefore garnering the regular profession's hostility) because they were being used to good effect overseas in the rehabilitation of wounded soldiers. However, the commission was less than impressed with the Hamilton school. It was what was known as a "straight" school: its instructors adhered to the pure doctrine that explained all illness by nerve deficits, and for all ills, they advocated manipulation only — the laying on of hands, with no devices or apparatus or medicine. Even worse, "straight" chiropractic theory rejected bacteriological explanations of disease: germs were not the cause but rather the indicators and products of toxic conditions. "Straight" chiropractic dismissal of bacteriological explanations went to the heart of the difference between alternative and regular medicine and held on to an earlier way of thinking. As John Crellin

explains, before the establishment of the germ theory, "treatment [was] tailored not just to the disease, but also to the constitution, faith, feelings, and experiences of the patient . . . . It was commonly believed that each individual possessed a specific constitution; in consequence, individuals were thought to react to disease and treatment in different ways."[14]

B. J. Palmer, son of the founder, appearing as an expert witness before the commission, stated, "The chiropractor did not believe in bacteria . . . . Bacteriology was the greatest of all gigantic farces ever invented for ignorance and incompetency," and he further considered analysis of blood and urine as "of no value."[15] Similarly, Ernst DuVal, head of the college in Hamilton, stated that "chiropractors have no earthly use for diagnosis," by which he meant the methods used by conventional medicine.[16] Although Commissioner Hodgins approved of the chiropractic technique of manipulation, he followed regular doctors in being critical of the unscientific thinking provided by Ontario's chiropractic schools. The Ontario schools soon closed.

Meanwhile, in the United States in the 1920s, laws came into effect that required all applicants for any type of medical licence to pass examinations in anatomy, physiology, pathology, and other subjects.[17] Students trained at chiropractic schools did poorly compared to regularly trained doctors, and diploma-selling scandals hurt the chiropractic reputation further. In Ontario, the dramatic improvements in orthodox medical training — full-time faculty were now common and laboratory science training had become more rigorous — meant that chiropractic education had less to offer in comparison.

While to orthodox doctors, medical technology's image shone brighter in this period, chiropractic's response to machines and devices was complicated and ambivalent. Despite the ability of the X-ray to "see" bones, most early practitioners were as violently opposed

Figure 23. *The physiotherapy department at Colonel Belcher Hospital, Calgary, a veterans' hospital, in the 1920s, featured tables and beds constructed of wood, and no apparatus more complex than lamps.*
(Glenbow Archives, NA-2901-12)

to using X-rays as they were to prescribing drugs. However, as the benefits of scientific medicine, the relevance of germs, and the advantages of drugs began to win over the public, chiropractic practitioners gravitated into two camps (with many variants).[18] The "straights," including the early Ontario practitioners described above, rejected any forms of drugs and any extension of the range of therapies. The "mixers," by contrast, were more interested in the business of building a practice that could compete with orthodox medicine and with other types of healing. One mixer college in the United States advertised that it included training in the following physiotherapeutic devices that could enhance adjustments: "the Solar Therapeutic Lamp and the Electric Light Bath Cabinet . . . the Arc Lamp, Centrifugal Vibrator, Diet Indicator, Kellogg Douche . . . Dynometer, Hand Photophore . . . Sinusoidal Apparatus, Thermophore and Vibratory Chair."[19] This list includes borrowings from hydrotherapy, electric and magnetic therapy, and radiotherapy, some of which were used by orthodox doctors as well.[20] By 1912, some chiropractic practitioners began to use X-ray machines to guide their manual treatment. In the 1920s, many of the second-generation leaders of the profession tended to be "mixers."

In 1924, B. J. Palmer introduced the neurocalometer, devised by his colleague Dossa D. Evans, and proclaimed it to be the only legitimate chiropractic diagnostic technology. A type of thermometer, the machine was supposed to measure the heat of nerves when drawn along the spine and more easily locate a subluxation.[21] Palmer, leader of the "straights," patented the neurocalometer and planned to prevent the 20,000 "mixers" then in practice from using it.[22] The sales of the neurocalometer were at first brisk, though numerous imitations, such as the "Hotbox Indicator," quickly arrived on the market. Soon, however, the "mixers" reacted against B.J.'s marketing scheme. (He demanded a $1,000 deposit and ten years of monthly lease payments.) The advent, or at least the marketing, of the neurocalometer resulted in a breakaway group of new schools, and further tarnished the reputation of chiropractic.[23] In Ontario, the governing body of chiropractics (now dominated by "mixers") passed regulations demanding more science-based education as a prerequisite of licensed practitioners, thus preventing Palmer School graduates from qualifying.[24]

Chiropractic also began to gain some of the privileges of conventional medicine in Canada. The first of the regulatory statutes governing the practice of chiropractic was adopted in Alberta in 1923, and the other western provinces followed in the 1930s and 1940s. In Ontario, chiropractors (with osteopaths and naturopaths) were allowed to practise with limited rights under the Drugless Practitioners Act of 1925, though a separate regulation of that period meant that they were no longer allowed to use the title "doctor" (and prosecutions did follow).[25] Changes to legislation in 1935 and 1937 permitted chiropractors to diagnose as well as treat. These changes, the Ontario Medical Association complained, allowed chiropractors to use the provincial laboratories,[26] because they were no longer legislatively prohibited from ordering or performing laboratory tests.[27] In 1937, Ontario was the first province to include chiropractic services under the Workmen's Compensation Act.

Canadian chiropractors formed a national organization that in 1945 opened the Canadian Memorial Chiropractic College in Toronto. Its graduates elevated the number of practitioners working in Canada from 400 or 500 in 1946 to more than 700 six years later, despite receiving no public funding.[28] By 1950, the college was accredited as a school of anatomy, bringing it closer to other medical educational institutions. Its program earned criticism from the "hands-only" western provinces and praise from the "broad-scope" provinces of Ontario and Quebec. Firmly "mixer" in orientation, the college made instruction in physiotherapeutics mandatory and continued to promote instruments into the 1960s. Despite continuing controversy, it developed and sold the "Posturizer" and "Posturometer" and later the "Synchro-Therme," a type of neurocalometer (though the latter was not approved by the Food and Drug Administration in the United States so revenues were disappointing).[29]

The history of chiropractic is marked with internal dissension, disreputable behaviour of prominent practitioners, poor levels of professional education, suspect theory, dubious efficacy, and constant attack by the regular medical profession. Yet "quackopractic," as some sneeringly called it, continued to exist and achieved varying degrees of official recognition in Canada and the United States because it had significant popular support. Further, some of these same criticisms could be applied to orthodox medicine, as the history of chronic illness demonstrates.

Arthritis, Cancer, and Unorthodox Therapy

Alternative medicine flourished where regular medicine was ineffective, in the treatment of chronic and terminal illness. The first example is the career of the "toe-twister," Dr Mahlon Locke. His story demonstrates that patients will try a variety of cures, regular or not, particularly if they are inexpensive and not unpleasant.[30] Locke put the village of Williamsburg, near Ottawa, Ontario, on the map as a centre of alternative healing in the 1930s. He was a regularly trained doctor whose specialty was manipulating the

bones of the feet for relief of a wide variety of conditions. Many of Locke's patients suffered from painful arthritis. Like chiropractors, Locke considered that his job was to allow natural healing by unblocking the channels of health: manipulation relieved the pressure on the arches and therefore on the veins and arteries of the feet. Locke provided many thousands of individual treatments at $1 per "twist." He developed a unique technology of service delivery. Sitting in a swivel chair on a concrete slab, with "his patients lined up — on foot, on stretchers and in wheelchairs — like the spokes of a wheel,"[31] Locke spun in a circle, treating one person each minute, up to 2,700 people per day!

Locke expanded his reputation, services, and income with arch-support footwear he designed and had manufactured locally. He also designed shoe inserts, called "cookies," to spread pressure across the soles. Locke's technique of toe-twisting seems to have died with him, a fact that shows the importance of the founders of unorthodox sects or practices, although the technology he developed — orthopedic shoes and "cookies" — has survived. Locke's work did not include personal relationships with his patients: how could it, in one minute? He offered a simple, cheap, painless, technologically interesting technique.

Although the arthritis, rheumatism, and other diseases suffered by Locke's patients could be crippling and painful, cancer was the most dreaded of human afflictions. Unorthodox medicine has always flourished in its shadow. Barbara Clow has studied the health care choices of cancer patients in Ontario in the first half of the century, and this section relies heavily on her work.[32] By describing the practice and careers of three conventionally trained healers who practised in the decades between the wars, she has also explored the logic that patients and regular doctors used, and the power they wielded in the health care environment. The popular and official response to these healers was directly related to the costs and failures of orthodox technology used in cancer treatment.

As already noted, the cure rate was poor for many types of cancer, and death commonly followed the diagnosis. What caused cancer was still unknown in the late 1920s. Cancer patients and their families were told that early detection was the key to a cure, yet they also knew that the disease in its early stages was routinely misdiagnosed by regular doctors. The main remedies were horrendous: repeated surgery or radiation, accompanied by pain, disfigurement, and disability, without much hope of survival when the disease was far advanced or when tumours were too deep to reach by radiation or too attached to vital tissues for surgery. In extreme need, patients kept their options open and continued to consult regular doctors and ask for opiates to relieve their suffering. However, it is not surprising that individuals terminally sick with cancer also turned to milder treatments dispensed by healers who offered more time for the patient and were interested in the individual as well as the disease.

One approach of cancer healers was to spurn the machine and the knife and return to the natural, via botanical and mineral treatments and diets. These healers often derided the use of orthodox medical technology as cruel and futile. Perhaps the most famous cancer healer of the interwar period was Rene Caisse, a nurse from Bracebridge, Ontario, who promoted a herbal tea made using her own secret formula. "Essiac" (her surname spelled backwards) was based on an infusion that an aboriginal woman had given her. Its main ingredients were burdock root, sheep sorrel, rhubarb root, and slippery elm bark, though Caisse kept the recipe to herself at first.[33] Caisse tried Essiac on mice and also tested it on herself, as was common with scientific experimenters in this period. In the 1920s, she began to dispense Essiac to thousands of patients. The tea had no unpleasant side effects and Caisse did not charge for her work, an important strategy that insulated her to some extent from legal harassment. She was praised by patients for her kindness and the deep interest she displayed in their lifestyle, beliefs, and illness experience. Despite pressure from licensed practitioners, the Ontario Liberal government of Mitch Hepburn did not prosecute Caisse for practising without a licence, fearing an angry backlash by voters at election time. Lay support for Essiac was high in the 1930s (55,000 signed petitions in support in the 1930s)[34] but dimmed, as did that for most alternative medicine, in the postwar period. The Essiac formula was purchased by the Resperin Corporation in the late 1970s and remains a widely used if controversial treatment for cancer to this day, in the United States as well as in Canada.[35]

The work of a second cancer healer was more in keeping with contemporary scientific interest in enzymes and more complementary to orthodox medical technology. In the 1930s, a medical doctor named Hendry Connell, in Kingston, Ontario, announced that a preparation he had developed, named Ensol, had resulted in remarkable clinical effects in nearly two thousand patients treated.[36] Ensol was an enzyme solution that, he claimed, digested cancer cells while leaving normal cells unharmed. Connell quickly established a research foundation and published his findings. His work instantly attracted the attention of cancer sufferers, doctors, and funding bodies. The DuPont Company provided $125,000 to Connell (and the equivalent to another research outfit in the United States to investigate the serum) in return for the U.S. patent rights for Ensol. The Ontario Department of Health also invested in his research, by providing funding and human cancer tissue, because its officials

hoped that Ensol would be as effective as and cheaper than radium therapy.

The idea of a serum against cancer was not new. In the 1930s, the Canadian physician Thomas Glover claimed that he had found a microscopic organism that caused cancer and had developed a serum treatment that killed it.[37] Clow argues that the positive response Ensol received was partly because Connell was well connected inside the profession and because he cooperated with authorities by sharing his formula, his animal research results, and his patient case files. Connell did not threaten orthodox cancer specialists because he played within the rules, encouraging patients to undergo radiation and surgery in addition to Ensol therapy. However, in 1938, eleven patients in the United States died from Ensol contaminated with tetanus toxin. Although Connell's lab did not produce the bad batch, the disaster drew attention to the quality of Connell's research, the vagueness of his theories, and the uneven consistency of the Ensol. Connell's public funding was cut off in 1945.

Another member of the social and medical elite claimed to have developed a powerful cancer treatment, but he met with professional censure partly because he offended the formal rules of scientific research. John Hett of Kitchener, Ontario, developed a serum treatment that was not as well received, despite its good fit with medical interest in glands and viruses, because he refused to divulge his formula.[38] In addition, his injection therapy was expensive. Hett was disbarred from practice in 1952 and later prosecuted for practising without a licence. There was no public outcry on his behalf, though his serum continued to be dispensed until 1968, more than a decade after his death.[39]

Alarmed at the popular enthusiasm for these and other unorthodox remedies, the medical profession pressured the Ontario government to act. The result was the Commission for the Investigation of Cancer Remedies, set up in 1938 and lasting more than two decades. Its goal was to investigate the efficacy of unconventional remedies and identify potential treatments. As Clow shows, though the commission attempted to test alternative therapies against the "gold standard" of scientific medicine, its investigations were restricted in deference to public enthusiasm for unconventional medicine. Popular opinion suspected the profession's motives in this campaign and also held that the science behind conventional medicine was not so different from the unorthodox.[40] For instance, randomized clinical trials were not the norm in regular medicine until the 1950s.

In the aftermath of the Second World War, conventional medicine consolidated its power in cancer care as elsewhere, and official anxiety about alternative medicine, as well as state support of unconventional medicine, declined precipitously. In the 1960s the cancer commission was disbanded after a dormant decade. In sum, Clow has shown that the response of both members of the regular profession and patients to unorthodox medical technology and practice depended not so much on the efficacy of the therapy but, on the one hand, the threat it provided to established medicine, and on the other hand, its public appeal relative to orthodox medicine.

Home Medicine and the Place of Women

The first diagnosis of illness usually happens at home, and until the last half of the twentieth century, the home was where birth, death, and the care of the ill took place. In 1910, in New York City, about 90 percent of the care of the sick took place in private homes, and similar heavy expectations for primary care were also likely placed on Canadian households, especially their women.[41] We have seen that the vast majority of tuberculosis sufferers never entered sanatoria or hospitals. Accordingly, manufacturers of the early twentieth century made apparatus and devices for the home sickroom or tent, including special "klondike beds" for outdoor sleeping and "Knopf indoor window tents" that extended the bedroom or balcony and exposed the patient to fresh air and sunlight.[42] Because the required equipment (the manometer and other apparatus) was portable, the tuberculosis collapse therapy known as pneumothorax was often performed in the home.[43] Anaesthetic apparatus was also simple, so that operations at home were both possible and less costly than hospital surgery in the days before public health care.[44] Seniors have recounted stories of doctors performing trepanning (opening the skull to relieve pressure) on the kitchen table and children operating on their desperate mothers.[45] Rosemary Stevens has shown that "portable surgical kits, including folding operating tables, continued to be marketed well into the [twentieth] century."[46] One historian of medical technology reminds us that "wet cloths, mud baths, sun baths, drying concoctions, special diets, and drugs" are all physical agents used to curtail disease and relieve discomfort,[47] and they were mainstays of home medicine and self-care long before modern medicine.

If home was where health care was provided, women were the family nurses who wielded medical apparatus and guarded the medicine chest. Only well-to-do families could afford private nursing, the main type of nursing until the 1920s. In the United States, it was quite common in the first decades of the century for female relatives of the patient to be present during an operation, even when it took place in a hospital.[48] In most Western

cultures, women were considered to have special knowledge and other qualities required in caring for the sick. They were the charmers and midwives and keepers of folk remedies, and female family and social networks have maintained and promoted a shared knowledge of self-care.[49] Among the culturally distinct, sparse, and isolated populations of Newfoundland, Quebec, and the Prairies, a rich tradition of home medicine developed and persisted.[50] Characteristics of early self-care in Newfoundland include its gendered nature, its initial dependence on local ingredients, and its religious and magical overtones, evident in the use of charms and amulets to ward off sickness.

Within home medicine, or self-care, John Crellin includes concoctions made at home, bought remedies, and rituals and procedures meant to prevent or cure sickness.[51] For Newfoundland, Crellin has compiled an encyclopedia of long-established remedies captured in oral history and in recipe books.[52] These were used for a wide range of ailments, accidents, and for predicaments such as unwanted pregnancy. Liniments, poultices, and mixtures feature juniper, spruce, goose grease, and bearberry, cooked up on stoves or brewed in jars. In contrast, as one child of homesteaders recalled, there were only a few medicines in Prairie immigrants' home medicine chests: "The Epsom salts were used to clean wounds of man and animals too, the dry mustard was used for mustard plasters on the chest, and of course, the aspirin was used to cure everything else."[53] Some settlers of the Prairies brought recipes from Europe such as sulphur and molasses mixtures for spring tonic. Yet other newcomers, confronted with the strange flora of their new land, turned to neighbouring aboriginal people and adopted their botanical recipes and remedies.[54]

Home medicine, therefore, was not static. With the nineteenth-century boom in patent medicines and the rise of drugstores and pharmaceuticals that followed, the home slowly was displaced as the site where medicines and other remedies for illness were

Figure 24. *Most individuals with tuberculosis could not afford sanatorium treatment. This well-organized 1913 Toronto household erected a tent complete with electric light, wood stove, and bell system to make the isolation of their tubercular family member more comfortable.*

(City of Toronto Archives)

concocted, as the example of Newfoundland once again shows. Islanders commonly expressed a preference for exotic ingredients, starting with drugs and medicines from natural but foreign sources, such as cod liver oil bottled in other countries. Beginning in the 1920s, following the trend in most of the country, Newfoundland families also began to substitute commercial patent medicines for their homemade concoctions.[55] Access explains part of this shift: commercial remedies were readily available over the counter in the new shops called drugstores, and by mail order from about 1900, and elsewhere from travelling salesmen. Crellin relates the successful career of Gerald S. Doyle (1892–1956), who used old recipes and new formulae to offer preparations in a string of drugstores he opened; he publicized these in folksy radio broadcasts from the 1930s.[56] Convenience is a second explanation. Drugstores shortened the steps in making home medicines; for instance, they stocked products used to prepare medicines in the home, such as packets of herbs, and they also dispensed special concoctions or recipes on the instructions of their customers.[57] Compared to liquid concoctions that took days of brewing or cooking, pills and tablets, for instance, were instantly available and easy to store and to ingest.[58] At the same time, folk remedies began to seem old-fashioned compared to scientific, store-bought medicine.

One facet of the popular interest in commercial medicine was that Canadians had become less tolerant of illness and infirmity, and more interested in prevention they could buy in a bottle or otherwise easily acquire. Newfoundlanders' health at the start of the First World War was cause for alarm: 57 percent of conscripts were declared medically unfit to serve, weakened by infectious disease and poor nutrition.[59] Against "weakness," manufacturers offered bodybuilding equipment such as the Loop Developer.[60] Through advertising in newspapers and on radio, they also marketed vitamins and food supplements. Such concoctions and preparations had existed from the 1870s, when malt drinks, brown flour, beef extracts like Bovril, and commercial breakfast cereals like Kellogg's Grape-Nuts were promoted as preventatives and restoratives against the pervasive problem of "weakness."[61] However, in the late 1920s, vitamins, a new product class between drugs and food, became immensely popular against deficiency diseases (rickets and beriberi, for example).[62] Women were eager consumers of vitamins as well as tonics, patent medicines, and diet supplements, such as Lydia Pinkham's Vegetable Compound, Dr Chase's Nerve Food, and Siegel's Syrup.[63] (They also purchased contraceptive devices and preparations, and medicines that promised relief of "female irregularity," usually meaning pregnancy.)[64]

In the 1930s, the federal government responded to professional medicine's warnings that unregulated patent medicines and foods, especially those that contained cocaine, strychnine, and opiates, could damage public health. A Canadian Food and Drug Act amendment of 1934 drastically narrowed the products that could be sold without prescription by limiting the content of advertising to the public, though patent medicines continued to be popular.[65] In particular, preparations based on old ideas of disease causation continued to sell. Popular faith in depleting medicines and products to purify the blood was reflected in sales of Epsom salts and Dodd's kidney pills, long after mainstream medicine lost interest in theories of autointoxication.[66] Similarly, the ancient belief that illness often arose from sudden changes in temperature was featured in home remedies such as poultices designed to reduce or increase the heat of the body or its specific parts. Canadians continued to employ a wide variety of practices and types of intervention when illness struck.[67]

Meanwhile, advocates of scientific motherhood argued that women could best fulfill their traditional responsibilities in the home by learning the theory and practice of modern nutrition. In Canada, Adelaide Hoodless worked for better household education of mothers and future mothers. In 1897, she founded the Ontario Women's Institutes for rural women. She campaigned for the teaching of domestic science in public elementary schools, achieved in 1904. Her textbook taught generations of girls that they were perfectly capable of mastering the science of nutrition. The kitchen her "young housekeeper" is confidently in charge of looks like a laboratory (Figure 25), with its wall chart, benches, and sinks.[68] Women were to be domestic scientists, promoting the health of their families and the health of the nation. Hoodless was an advocate of scientific technology and in 1909 advised Prime Minister Sir Wilfrid Laurier that Canada should develop a national research school of technology modelled on the German example.[69]

Nutrition for infants and children also moved into the domain of research clinicians in the 1920s, a development that arose from the desires of medical and social reformers to improve child welfare and control maternal practice. In 1930, at the Hospital for Sick Children in Toronto, the paediatrician Allan Tisdall and his team developed Sunwheat, a biscuit for children that contained all the known necessary vitamins, wheat germ, and minerals. With his colleagues Allan Brown and Theodore Drake, Tisdall launched Pablum, an infant food made of mixed, dried, and cooked cereals, in 1931. The scientists negotiated with McCormacks in Toronto to manufacture Sunwheat and with Mead Johnson in the United States to manufacture Pablum. For twenty-five years, royalties from sales were returned to the Toronto Paediatric Foundation's research fund.[70] Later, Tisdall and his colleagues pushed the

addition of vitamin D to bread, flour, and milk. The mass newspaper and radio coverage of the Dionne quintuplets in the 1930s also set an enduring fashion for Carnation milk as infant food in preference to breast milk.[71] Jaclyn Duffin has noted that the sterilizable rubber nipple, invented in 1845, relieved anxiety about the hygiene of artificial feeding of infants.[72] The glass baby bottle that registered the amount consumed (and sometimes was equipped with a thermometer that guaranteed formula at the correct temperature) is the purest example of the shift from homemade to commercially prepared foods and to a regulated diet.[73] However, most women continued to breastfeed (with the approval of most doctors), and in general to be responsible for their family's nutrition, hygiene, and the care of the sick, most of which continued to be home-centred.

In complex ways, the public health movement changed the image and the practice of women's role as guardians of family health. On the one hand, activists underlined the crucial importance of domestic hygiene and nutrition. Yet they also fretted about the skills and knowledge that women employed. In Canada as in Britain, middle-class women became strong promoters of public sanitation and domestic hygiene.[74] They aligned with doctors to demand healthy homes that featured indoor plumbing and hot water's germ-killing qualities. Mothers cast off Victorian microbe-making clutter in favour of smooth surfaces that could be disinfected, and they bought vaporizers and other special equipment that promised to keep sickroom germs away from the rest of the house. The iconic pieces of hygienic domestic technology are the porcelain toilet and the washing machine, though most Canadian

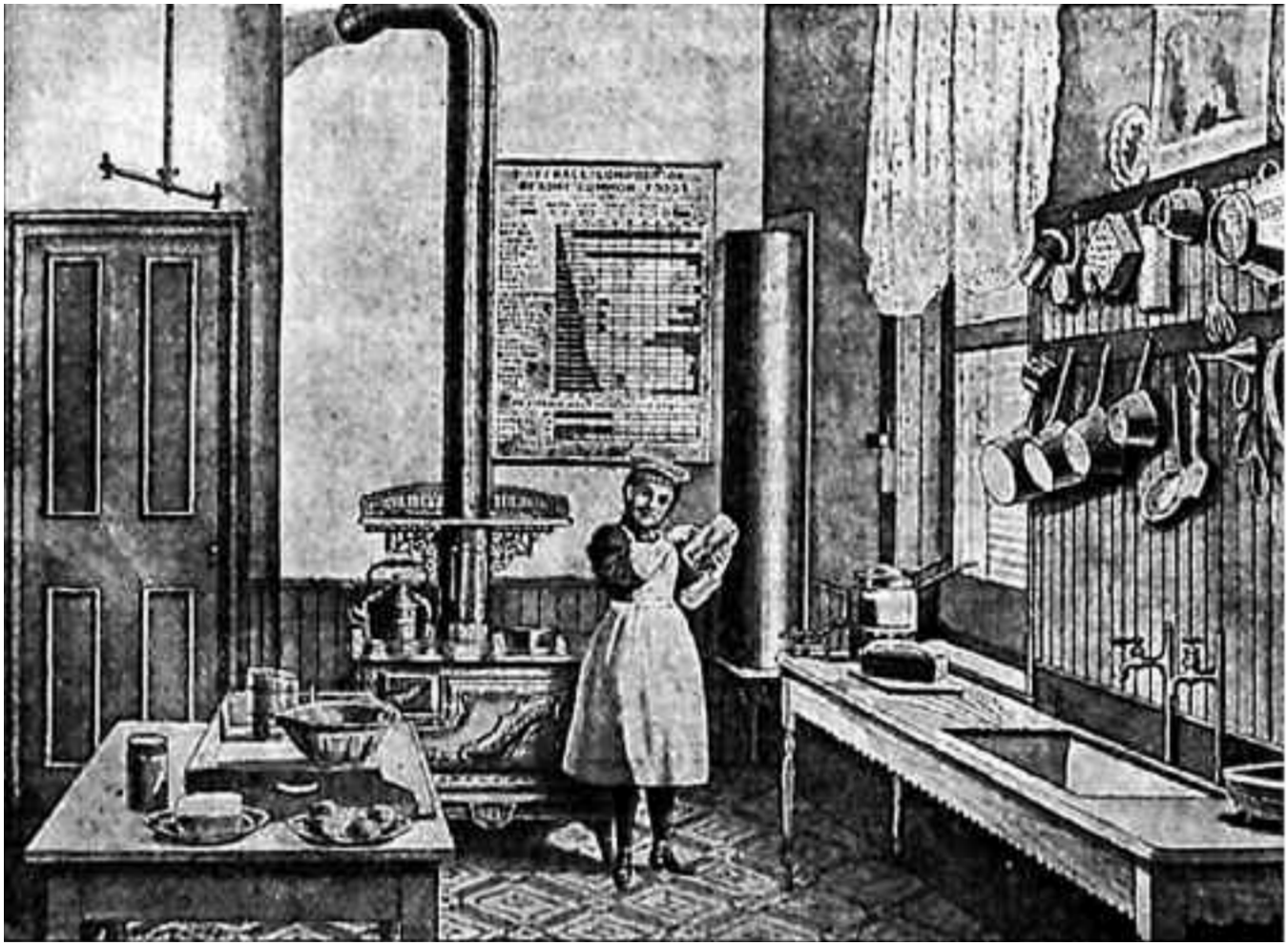


Figure 25. *Adelaide Hoodless's imaginary "Young Housekeeper" practised the new domestic science in the ideal kitchen, 1898. The easy-to-clean sinks and benches, stainless steel equipment, nutrition chart, even the apron and cap were modern technology for the home health professional — the new woman.*

(*Public School Domestic Science* [Toronto: Copp Clark, 1898])

families had to wait for indoor plumbing until after the First World War.[75] Yet women's authority over the health of the home and family had begun to crumble in England by 1900, according to Annmarie Adams. Adams draws a parallel between the home and women's bodies, both of which were the subjects of physician's increasing interest and interference in the era of germ warfare.[76] For example, sanitary activists viewed the home itself, especially the immigrant home, at best as a battleground against germs, and at worst as their breeding ground. In Toronto, Ottawa, and Hamilton, house-to-house inspection allowed "municipal housekeepers" searching for substandard cleanliness and sanitation to enter private homes.[77]

The sanitary shortfalls in urban domestic life meant that by the 1920s, the hospital, not the home, was the model institution of health, safeguarded from contagion by its aseptic technology. But women also wanted the best for their sick family members, and the hospital was the source for the latest technology. X-ray apparatus, short-wave diathermy machines, surgery, chemical tests, and other increasingly complex procedures and devices required electricity and water on a scale beyond what the home could provide, along with trained nurses and physiotherapists for patient care. Mothers, wives, and daughters did not necessarily resent being supplanted, because the duties of home nursing could be onerous.

For many women in rural areas, however, childbirth continued to take place at home into the 1940s. Where doctors were sparse — on the Prairies, in the Far North, in aboriginal communities, in Newfoundland, and where women could not afford doctors (among the poor in days before medicare) — midwives and nurses provided with simple technologies whatever medical assistance was available.[78] Nurses in rural areas commonly administered anaesthetic and gave hypodermic injections in the absence of doctors. However,

Figure 26. *The crowded kitchens of the urban poor shared little more than a stove with the ideal domestic workplace. Most city homes, like this one from 1916 immortalized in Toronto by a public health department photographer, were without running water and indoor toilets until the 1920s.*

(City of Toronto Archives)

while midwives could offer a longer period of service than doctors (they often provided aftercare of cooking, cleaning, and nursing),[79] they generally had no access to forceps or anaesthesia. Women assisting at home births used materials at hand to imitate, as best as possible, modern apparatus. For example, wicker baskets and warming ovens in Prairie homes were turned into makeshift incubators for fragile newborns.[80] These were distant cousins to the complicated "machines in the nursery" developed by American physicians for hospital use.[81] However, by the second quarter of the twentieth century, the midwife's kit was beginning to look like the doctor's bag, for it contained enemas, lubricants, and sterile and sterilizing equipment such as rubber gloves, sterile pads, and equipment to boil instruments.[82]

In urban areas, childbirth began to move out of the house and into the hospital in the 1920s. One of the first regular medical interventions that modern hospitals specialized in was doctor-directed childbirth, and physicians had begun to take over from midwives in urban areas in the late nineteenth century, partly because they could provide a range of anaesthetics and analgesics (pain relief) in hospitals. Chloroform and ether, first used in Canada during childbirth about 1848,[83] could be administered at home, but chloroform could cause serious cardiac side effects and was phased out about 1920. Between the wars, safer options such as "twilight sleep" (scopolamine and morphine) were implemented. Spinal and local anaesthesia used heavy gas cylinders that were less portable, and therefore required the hospital setting.[84] Although anaesthesia by gas has contributed to putting the doctor firmly in control of labour, there did exist machines that allowed the patient to administer analgesic to herself, though not with the approval of at least one prominent Montreal doctor. Self-administration, considered acceptable in the 1920s by some doctors, and the subject of research by doctor-inventors, died out before mid-century.[85]

The hospital trumped the home for childbirth for a related reason: the growing probability that surgery and apparatus would be required during labour and delivery. The technology of anaesthesia, and especially the use of the gas cyclopropane, developed in Canada as described in an earlier chapter, encouraged a dramatic rise in popularity of the Caesarian section between the world wars.[86] This also reflected doctors' preference for a surgical solution for difficult cases (and the influence of gynecology on obstetrics).[87] The Caesarian section was justified by use of an instrument called the pelvimeter, which measured the cervix and helped the doctor predict when a labour might be difficult. A Caesarian section could save a woman's life in difficult or protracted deliveries without sacrificing the foetus; the foetus could be delivered whole instead of being dismembered by the old procedures known as embryotomy or craniotomy (for which there were special tools, the perforator and the blunt hook and crochet, to reduce the size of the infant brain).[88] Other instruments and procedures introduced into childbirth were made possible or indeed necessary with the use of anaesthesia: the catheter, induction and speeding of labour (through the drugs ergot or pituitrin and by the artificial rupturing of amniotic membranes), the episiotomy (incision of the perineum), and forceps. Canadian rates of forceps use varied across the provinces, but in general, they were probably lower than those in the United States and higher than European practice, rising to almost 50 percent in hospital births before the Second World War.[89] As Wendy Mitchinson argues, "Intervention led to intervention," and hospitals were deemed more appropriate sites than homes.[90]

Debates flared and died in the medical press as to the appropriate conditions for intervention in childbirth and the dangers that forceps and other interventions brought to mother and infant. Alternative medical systems such as homeopathy stressed that childbirth was a normal physiological process and that the best assistance any practitioner could provide mother and child was to allow Nature to take her course. However, by 1950, most Canadian births were hospital births, and Canadian women were not interested in "natural childbirth" again until the 1960s.

Aboriginal Medicine

Aboriginal medicine is not usually included in histories of alternative medicine because it constituted the dominant rather than the secondary set of healing practices in over one hundred different aboriginal cultures in North America in the pre-contact and contact eras. This brief discussion, centred on Native peoples who lived on the west coast and the prairies of Canada, does not aim to reduce the ancient beliefs and practices of culturally distinct peoples to a handful of simple concepts. It aims instead to show by examples that aboriginal medicine in the early twentieth century had its own technologies. These technologies (like other aspects of aboriginal life) did not disappear with the advent of Western medicine but evolved in response to new ideas of health and disease.

Despite its ancient and separate existence, aboriginal medicine shares with Western alternative systems the belief in holism, or the unbreakable connections of mind with body and the individual with society. Thus, Native concepts of health and disease encompass all facets of life; a broad range of behaviours in the human world, and agents and entities in the animal and spirit world, could cause or cure disease. For instance, prevention of sickness was the responsibility

Figure 27. *Aboriginal systems of healing included special material aids and instruments. In this photograph, circa 1910, a healing shaman of Kitwanga, a Tsimshian village, is treating a sick boy.*
(Canadian Museum of Civilization)

of all members of the community, because improper human behaviour could bring on illness. Rituals around hunting had to be conducted carefully, by showing respect to prey animals, or sickness could result. Through such cultural practices, all members of the community were responsible for the health of each individual.[91] Similarly, the role of healer among many Pacific coast peoples was unspecialized and larger than that of the Western personal physician: besides diagnosing and curing sickness in the individual, the healer also, according to the historian Mary-Ellen Kelm, "controlled the weather, ensured success during war or on hunting [or fishing] expeditions, foretold the future, communicated with those who were far away, and found lost items or people."[92] In other cultures, such as the Kwakiutl and the Plains Cree, the functions of diagnosis and therapy did not reside in the same individual: some performed diagnosis, and others attempted what might be called restoration of the individual's spiritual strength or supernatural power.[93]

Native belief in the interrelationship between the human sphere and non-human worlds shaped the process of becoming a healer, the concepts of disease, and the material aids used in healing. Healers' quests for curing powers often required the aid of spirits, such as the whale or bear or wolf, as well as rituals of isolation, fasting, and cleansing.[94] Similarly, the considerable skills of the herbal healers in concocting analgesic, emetic, diuretic, and other botanical treatments were not enough in themselves;[95] herbologists needed the assistance of spirit powers such as the dog, known in some cultures to carry away the sickness.[96] Disease was imagined as a material loss, often a soul stolen or sucked out, by sorcerers, by the dead, or by other evil spirits.[97] Wasting away, bizarre behaviour, and many other symptoms were taken as evidence of soul sickness.

Disease was also believed to result from three-dimensional objects intruded into the body. Insects, sticks, stones, and bones could be "thrown" into the body by those wishing illness to befall someone. Correspondingly, the healer's role in these cases of enchantment was to retrieve the objects and to undo spells. Tlingit healers used non-human helpers to travel into the spirit world and help them find a stolen soul.[98] In some cultures healers used special tools to remove disease from a sufferer. Intruded objects were sucked

Figure 28. *Tsimshian shamans were entrusted with curing soul sickness by finding, trapping, and reuniting the lost soul with the sick person's body. The shaman used a soul catcher, such as this example made of a hollowed bear leg bone, acquired by a collector in 1879.*
(Canadian Museum of Civilization)

out or manipulated by the hands of the healer to the surface of the body, extracted without breaking the skin, then destroyed in special bowls or other containers to prevent reinfection.[99] One specially fashioned device, the "soul catcher," a hollow bone carved to make its ends appear as mouths, was used by west coast aboriginals to suck or blow disease from the sufferer. In their "curing bundles," Plains Cree healers included sucking tubes along with what the historian Maureen Lux lists as "sharp blades for bleeding, bags of plant material, and objects such as the skins of the animal spirits that aided the healer."[100]

The paraphernalia of healers were turned to collective as well as individual purpose. Masks, dress, costumes, drums, rattles, soul catchers, and healing bundles were featured in public healing ceremonies like the Sun Dance or sweating ceremonies that not only cured souls but also strengthened the relationships within social groups and between healers and the people. The carved masks and other ceremonial devices served to distance the shaman or healer from the person to be treated (and from the audience), in the manner that gowns, masks, and machines separate the regular doctor from the patient and enhance the physician's authority and healing power.[101]

Historians of medicine today are careful not to depict folk or traditional medicine, aboriginal included, as an inert body of knowledge and practices that was changed only by contact with Europeans or merely degraded by Western medicine. It is true that late-nineteenth- and early-twentieth-century non-aboriginals generally derided aboriginal medicine as quackery. Although aboriginal healers themselves were not usually brought to court for practising medicine without a licence, ceremonial aspects were prosecuted through anti-fraud and anti-witchcraft legislation.[102] Yet several factors encouraged the survival of aboriginal medicine. In the case of tuberculosis, Native peoples had only poor access to Western medicine and technology, and therefore continued to rely on aboriginal healing.[103] Aboriginals also turned to traditional medicine when confronted with illnesses such as spirit sickness, which had no Western equivalent. Even where they accepted white medicine for imported diseases like smallpox and tuberculosis, they rejected the Western ideas of causation that represented the aboriginal body as inferior and unable to withstand infection. They preferred to interpret these new diseases not as individual pathology located inside the aboriginal body but as deliberate infections by whites (in line with old beliefs that put evil intent at the core of sickness).[104] Lastly, aboriginal technology and practices proved resilient and adaptable. For instance, aboriginals readily incorporated the Christian god into their supernatural worlds; in their healing ceremonies, when soul-sucking was required, they added a crucifix and other Christian paraphernalia. In sum, in the decades around 1900, aboriginal medicine sometimes borrowed from, often conflicted with, and occasionally informed white, orthodox medicine.[105]

Conclusion

To examine the history of alternative practices is to also look critically at regular medicine. The orientation of orthodox medicine has been faulted for being biomedical and mechanistic: in the words of Michael Saks, "The body appears as divisible into parts that can be repaired on breakdown."[106] Critics argue that the regular doctor looks for pathology first and sometimes inappropriately in the patient rather than in the environment, and tends to see disease as the product of localized lesions rather than systemic or metabolic disorder. In contrast, attention to the patient's spiritual life beyond narrowly defined signs and symptoms of material existence is a central theme of other ways of healing. Holistic practice was typical of aboriginal healers, who visited the spirit world in their curing ceremonies; and of midwives and nurses, who helped

deliver babies but also looked after the mother and infant in the days following childbirth; of Rene Caisse, whose mild root tea was offered with sympathy; and of chiropractors, who offered a philosophy of living and an alternative to drugs for painful chronic conditions. Whereas regular doctors, particularly specialists, have tended to keep their technology in their own hands, alternative practitioners and traditional healers in the first half of the twentieth century have emphasized that health is a partnership between practitioner and patient. Thus, the "toe-twister" Mahlon Locke placed the tools of health, as he saw them, in the hands of his patients, by selling his shoes and inserts directly to the public. These features allowed alternative practices to exist, develop, and sometimes thrive, despite orthodox medicine's impressive strengths, into the twentieth century.

At 1950, however, the tide of alternative medicine was at a low ebb. After the Second World War, conventional medicine consolidated its authority through technological advances not only within medicine but also in warfare and industry. Antibiotics were truly delivering miracles; in contrast, botanical remedies and "natural cures" by mid-century seemed old-fashioned and quaint, rather than invested with the wisdom of the ages. Popular support for unorthodox practice declined as some unconventional practitioners were exposed as greedy as well as ignorant. The continuing criticism levelled by orthodox medicine that alternative remedies just did not work was picked up by a public impressed with modern medicine and unaware of the extent to which the latter was itself unscientific. The many strands of medical culture that existed at the start of the twentieth century had come together, by 1950, in the triumph of the biomedical paradigm.[107] Though the typical baby was now born in a hospital, and the institution was the centre of modern diagnosis and therapeutics, Canadians still depended to a large extent on the nurturing and care given by women and received in the home, in sickness and in health.

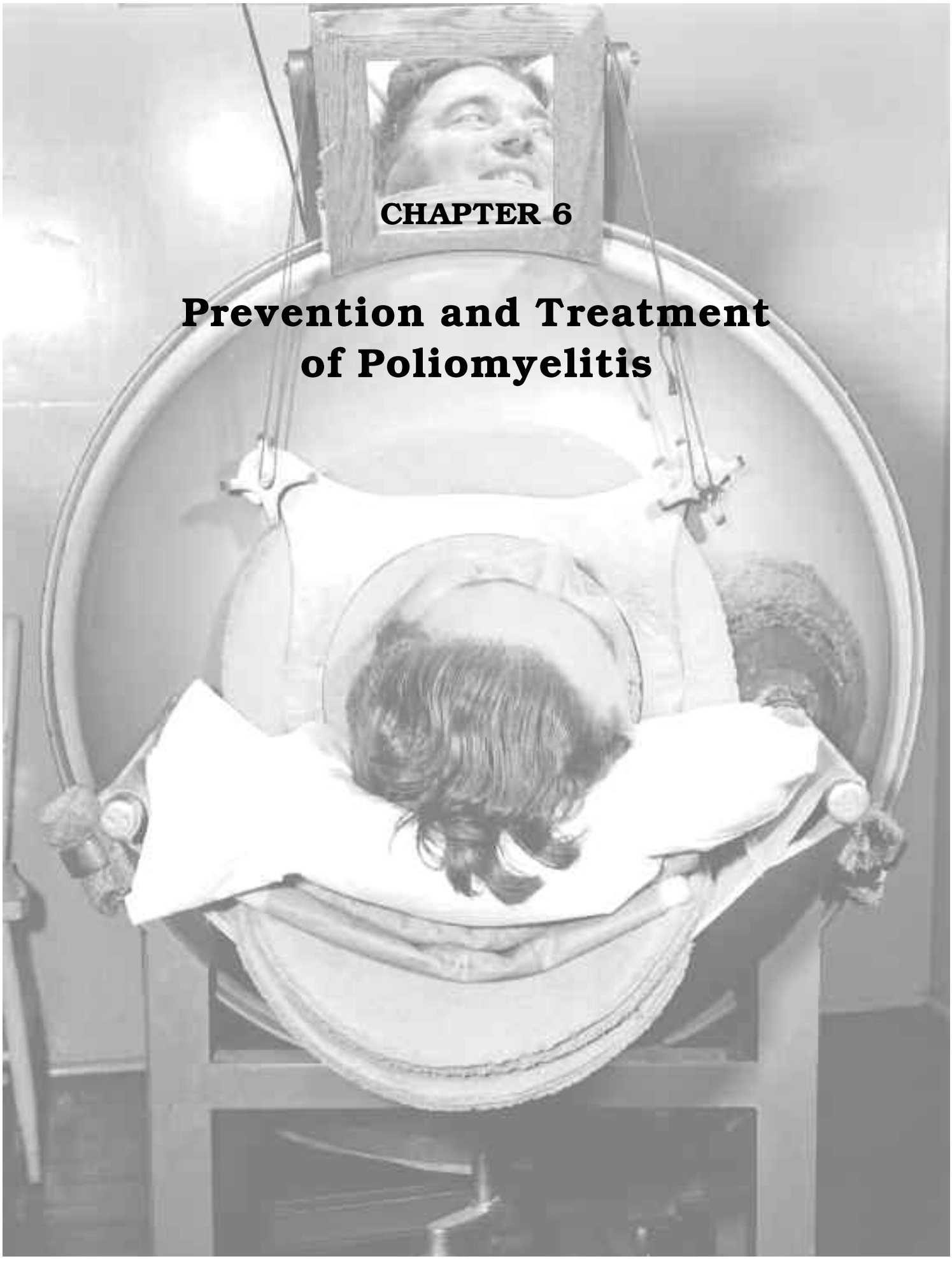
Notes

1. The terms *orthodox*, *conventional*, *allopathic*, and *regular medicine* are used interchangeably in this chapter.
2. Although the term *complementary medicine* is often used to describe the systems of healing touched on in this chapter, it is of recent usage and signifies a late-twentieth-century relationship of co-operation and harmony with regular medicine. We prefer the descriptors *alternative*, *unorthodox*, and *irregular* as accurate reflections of the legal and cultural status of these practices in the eyes of medical and other authorities of the day.
3. There is a substantial literature on nineteenth-century medical sectarianism and the efforts of orthodox medicine to secure a monopoly on health care. A small sample includes J. T. H. Connor, " 'A Sort of Felo-de-se': Eclecticism, Related Medical Sects, and Their Decline in Victorian Ontario," *Bulletin of the History of Medicine* 65, no. 4 (1991): 503–27; J. T. H. Connor, "Minority Medicine in Ontario, 1795–1903: A Study of Medical Pluralism and Its Decline" (PhD dissertation, University of Waterloo, 1989); R. D. Gidney and W. P. J. Millar, *Professional Gentlemen: The Professions in Nineteenth Century Ontario* (Toronto: University of Toronto Press, 1994); Ronald Hamowy, *Canadian Medicine: A Study in Restricted Entry* (Vancouver: Gage Distribution Co., 1984); Ronald L. Numbers, "The Fall and Rise of the American Medical Profession," in *Sickness and Health in America*, 3rd ed., ed. J. Leavitt and R. Numbers (Madison: University of Wisconsin Press, 1997): 225–36; John Harley Warner, *The Therapeutic Perspective: Medical Practice, Knowledge and Identity in America, 1820–1885*, rev. ed. (Princeton, N.J.: Princeton University Press, 1997); William G. Rothstein, *American Physicians in the 19th Century: From Sects to Science* (Baltimore: Johns Hopkins University Press, 1985); Margaret Brindle and Elizabeth Goodrick, "Revisiting Maverick Medical Sects: The Role of Identity in Comparing Homeopaths and Chiropractics," *Journal of Social History* 34, no. 3 (2001): 569–89.
4. Audrey Davis, *Medicine and Its Technology: An Introduction to the History of Medical Instrumentation* (Westport, Conn.: Greenwood Press, 1981), 6.
5. In 1907, Almeda Jane Haldeman opened perhaps the first chiropractic practice by a woman in Canada, and one of the earliest in Canada, in Herbert, Saskatchewan. Canadian Chiropractic Association website, www.ccachiro.org (accessed March 5, 2003). See also David Coburn and Lesley Biggs, "Legitimation or Medicalization? The Case of Chiropractic in Canada," in *Health and Canadian Society: Sociological Perspectives*, 2nd ed., ed. D. Coburn et al. (Markham, Ont.: Fitzhenry & Whiteside, 1987).
6. Canadian Chiropractic Association website, www.ccachiro.org (accessed March 5, 2003).
7. For a fascinating account, see Alison Winter, *Mesmerized: Powers of Mind in Victorian Britain* (Chicago: University of Chicago Press, 1998).
8. James Whorton, *Nature Cures: The History of Alternative Medicine in America* (New York: Oxford University Press, 2002), 165–6.
9. Ibid., 170–4. Osteopaths focused on the blood system; see Norman Gevitz, *The Dos: Osteopathic Medicine in America*, 2nd ed. (Baltimore: Johns Hopkins University Press, 2004).
10. David Edwin Harrell Jr, "Divine Healing in Modern American Protestantism," in *Other Healers: Unorthodox Medicine in America*, ed. Norman Gevitz (Baltimore: Johns Hopkins University Press, 1988), chap. 9.
11. Canadian Chiropractic Association, "For the Researcher," www.ccachiro.org (accessed March 4, 2003).
12. Whorton, *Nature Cures*, 187. J. C. Keating, "Building the Palmer Enterprises, 1913–1924, Part I," *Dynamic Chiropractic* 17, no. 13 (14 June 1999), www.chiroweb.com/archives (accessed November 15, 2007).
13. "Bony heretics" is used in the editorial "A Chiropractical Joke," *CMAJ* 5, no. 1 (January 1915): 49.
14. John K. Crellin, *Home Medicine: The Newfoundland Experience* (Montreal: McGill–Queen's University Press, 1994), 41.

15. *Report of the Royal Commission on Medical Education in Ontario*, 1917, Mr. Justice Hodgins (Legislative Assembly of Ontario, 1918), 125–6, cited in Donald C. Sutherland, "Chiropractic from Rejection to Acceptance, 1900–1980," *Journal of the Canadian Chiropractic Association* 42, no. 3 (1998): 164, www.jcca-online.org (accessed March 1, 2004).
16. Ibid., 125.
17. Whorton, *Nature Cures*, 231.
18. See Russell W. Gibbons, "Physician-Chiropractors: Medical Presence in the Evolution of Chiropractic," *Bulletin of the History of Medicine* 55, no. 2 (1981): 233–45.
19. Cited in Whorton, *Nature Cures*, 184.
20. A good example of this is electrotherapeutics. As argued by J. T. H. Connor and Felicity Pope, from the 1840s until the 1940s, Canadian physicians, lay practitioners, and the general public alike used electromagnetic machines, faradic batteries, and ultraviolet ray machines, among other devices, to treat a range of pains and ailments. See J. T. H. Connor and Felicity Pope, "A Shocking Business: The Technology and Practice of Electrotherapeutics in Canada, 1840s to 1940s," *Material History Review* 49 (1999): 60–70.
21. Whorton, *Nature Cures*, 189.
22. Joseph C. Keating, Carl S. Cleveland, and Michael Menke, "Chiropractic History: A Primer," 6, www.historyofchiropractic.org/ChiroHist%20Primer/primerall72.pdf (accessed February 28, 2008).
23. Whorton, *Nature Cures*, 189. Steven C. Martin, "Chiropractic and the Social Context of Medical Technology, 1895–1925," *Technology and Culture* 34, no. 3 (1993): 808–34; Joseph C. Keating, "Introducing the Neurocalometer: A View from the Fountainhead," *Journal of the Canadian Chiropractic Association* 35 (1991): 165–78.
24. C. Lesley Biggs, "The Silent Partner? The State's Role in the Formation of the Ontario Chiropractic Profession's Identity, 1925–1952," *Health and Canadian Society* 2, no. 1 (1994): 47.
25. Biggs, "The Silent Partner?" 42–6.
26. W. H. Noble, "A Study of Osteopathy and Chiropractic" (College of Physicians and Surgeons of Ontario, 1958), 10, cited in Sutherland, "Rejection to Acceptance," 166.
27. Allan C. Gotlib, H. Stephen Injeyan, and John P. Crawford, "Laboratory Diagnosis in Ontario and the Need for Reform Relative to the Profession of Chiropractic," *Journal of the Canadian Chiropractic Association* 41, no. 4 (1997): 208. In Ontario for a short period from 1972, only medical doctors and dentists were allowed to perform laboratory tests.
28. Sutherland, "Rejection to Acceptance," 166.
29. Joseph Keating, "Search for a Science of Straight Chiropractic: Herbert Marshall Himes," *Dynamic Chiropractic* (14 December 2000), 3, www.chiroweb.com/archives (accessed November 28, 2007).
30. This section relies heavily on Barbara Clow, "Mahlon William Locke: Toe-Twister," *CBMH* 9, no. 1 (1992): 17–39. Reprinted in *Alternative Health Care in Canada: Nineteenth and Twentieth-Century Perspectives*, ed. J. K. Crellin, R. R. Andersen, and J. T. H. Connor (Toronto: Canadian Scholars' Press, 1997); see also Robert Jackson, *Mahlon Locke: The Foot Doctor* (Toronto: Dundurn Press, 1991).
31. Pat McAdam, "He's a Shoe-in for Top Doc," *Ottawa Sun* (8 February 2004).
32. Barbara Clow, *Negotiating Disease: Power and Cancer Care, 1900–1950* (Montreal: McGill–Queen's University Press, 2001).
33. Ibid., 78 et al.
34. Ibid., 104.
35. Ibid., 156.
36. Ibid., 63–73.
37. Ibid., 47.
38. Ibid., 75–6.
39. Ibid., 153.
40. Ibid., 145.
41. "Hospital Shortcomings," editorial, *New York Medical Journal* 101 (1915): 29, cited in Rosemary Stevens, "Technology and Institutions in the Twentieth Century," *Caduceus* 12, no. 3 (Winter 1996): 10.
42. Katherine McCuaig, *The Weariness, the Fever and the Fret: The Campaign Against Tuberculosis in Canada, 1900–1950* (Montreal: McGill–Queen's University Press, 1999), 18–25.
43. Annmarie Adams and K. Schwartzman, "Pneumothorax Then and Now," *Space and Culture* 8, no. 4 (2004): 440–1.
44. On portable anaesthetic apparatus, G. B. Rushman, N. J. H. Davies, and R. S. Atkinson, *A Short History of Anaesthesia: The First 150 Years* (Boston: Butterworth Heinemann, 1996), 58–9; on hospital fees, Helen Heeley, comp., and Susan Charters, ed., *Life Before Medicare: Canadian Experiences* (Toronto: Ontario Coalition of Senior Citizen Organizations,1995), 19, 23, 39–40.
45. Heeley and Charters, *Life Before Medicare*, 9–13 et al.
46. Stevens, "Technology and Institutions," 14.
47. Davis, *Medicine and Its Technology*, 6.
48. Emily A. Abel, *Hearts of Wisdom: American Women Caring for Kin, 1850–1940* (Cambridge, Mass.: Harvard University Press, 2000), 108.
49. Mike Saks, "Medicine and the Counter Culture," in *Medicine in the Twentieth Century*, ed. Roger Cooter and John Pickstone (Amsterdam: Harwood Academic Publishers, 2000), 118.
50. Crellin, *Home Medicine*; Francine Saillant et Ginette Côte, *Se soigner en famille. Les recettes de médecine populaire dans les familles québécoises du début du XX^e siecle*, vol. 1 (Quebec City: Centre de recherche sur les services communautaires, Université de Laval, 1996).
51. Crellin, *Home Medicine*, 4–5.
52. One home care guide was T. Ritter's. See "The People's Home Medicine Book," in R. C. Barnum, comp., *The People's Home Library* (various editions including Toronto: Imperial Publishing Company, 1920), mentioned in Heeley and Charters, *Life Before Medicare*, 2.
53. Birgit Ethier, quoted in Heeley and Charters, *Life Before Medicare*, 1.
54. Maureen K. Lux, *Medicine That Walks: Disease, Medicine, and Canadian Plains Native People, 1880–1940* (Toronto: University of Toronto Press, 2001), 97–8.
55. Crellin, *Home Medicine*, 42. For illustrations from Newfoundland's history, see John K. Crellin, *A Social History of Medicines in the Twentieth-Century: To Be Taken Three Times a Day* (New York: Pharmaceutical Products Press, 2004), 51–142.
56. Crellin, *Social History of Medicines*, 28–9.
57. Ibid., 24.
58. Crellin, *Home Medicine*, 16.
59. Ibid., 22.
60. Crellin, *Social History of Medicines*, 57, Box 3.1.
61. Ibid., 59–66.
62. Jordan Goodman, "Pharmaceutical Industry," in *Medicine in the Twentieth Century*, ed. Roger Cooter and John Pickstone (Amsterdam: Harwood Academic Publishers, 2000), 144–5. See also Rima Apple, *Vitamania: Vitamins in American Culture* (New Brunswick, N.J.: Rutgers University Press, 1996).

63. Wendy Mitchinson, *Giving Birth in Canada, 1900–1950* (Toronto: University of Toronto Press, 2002), 31.
64. For the technology of birth control, see Angus McLaren and Arlene Tigar McLaren, *The Bedroom and the State: The Changing Practices and Politics of Contraception and Abortion in Canada, 1880–1980* (Toronto: McClelland & Stewart, 1986). Despite the illegality of his practices, Kitchener rubber manufacturer A. R. Kaufman manufactured and distributed to hundreds of thousands of Canadian women his diaphragms, condoms, and spermicidal jellies from the 1930s, for both eugenic and commercial motives. See Linda Revie, "More Than Just Boots! The Eugenic and Commercial Concerns behind A. R. Kaufman's Birth Controlling Activities," *CBMH* 23, no. 1 (2006): 119–43.
65. Crellin, *Home Medicine*, 27.
66. Ibid., 23–4. See also Francine Saillant, "Home Care and Prevention," *Medical Anthropology Quarterly* 12, no. 2 (June 1998): 188–205.
67. Crellin, *Home Medicine*, 5.
68. Adelaide Hoodless, *Public School Domestic Science* (Toronto: Copp Clark, 1898). See also Cheryl MacDonald, *Adelaide Hoodless: Domestic Crusader* (Toronto: Dundurn Press, 1986).
69. The prime minister replied that education was a solely provincial matter, an early example of the significance of our split jurisdictional system on the development of Canadian scientific institutions. Terry Crowley, "Hunter, Adelaide Sophia (Hoodless)," *Dictionary of Canadian Biography*, vol. 13, *1900–1910*, 491.
70. Cynthia R. Comacchio, *Nations Are Built of Babies: Saving Ontario's Mothers and Children, 1900–1940* (Montreal: McGill–Queen's University Press, 1993), 124. For more on infant feeding see Rima Apple, *Mothers and Medicine: A Social History of Infant Feeding* (Madison: University of Wisconsin Press, 1987); Rima Apple, *Perfect Motherhood: Science and Childrearing in America* (Chapel Hill, N.C.: Rutgers University Press, 2006); Veronica Strong-Boag, "Intruders in the Nursery," in *Childhood and Family in Canadian History*, ed. J. Parr (Toronto: McClelland & Stewart, 1982), 174–7.
71. Crellin, *Home Medicine*, 25, 95.
72. Duffin, *History of Medicine*, 319.
73. Annmarie Adams, *Architecture in the Family Way: Doctors, Houses and Women, 1870–1900* (Montreal: McGill–Queen's University Press, 1996), 127–8.
74. This paragraph relies on Adams, *Architecture in the Family Way*, 91–3.
75. Heather MacDougall, *Activists and Advocates: Toronto's Health Department, 1883–1983* (Toronto: Dundurn Press, 1990), 77.
76. Adams, *Architecture in the Family Way*, 102.
77. MacDougall, *Activists and Advocates*, 72–3.
78. Mitchinson, *Giving Birth*, 70. As argued by Dianne Dodd, the federal Department of Health issued a supplement to its widely read *Canadian Mother's Book*, part of the Blue Book series, written by Dr Helen MacMurchy, chief of the department's Child Welfare Division. This supplement was written exclusively for outpost women and their "untrained" neighbours who often assisted at births because no one else was available. See Dianne Dodd, "Helen MacMurchy: Popular Midwifery and Maternity Services for Canadian Pioneer Women," in *Caring and Curing: Historical Perspectives on Women and Healing in Canada*, ed. Dianne Dodd and Deborah Gorham (Ottawa: University of Ottawa Press, 1994), 135–61; for the medicalization of aboriginal childbirth, see Patricia Jasen, "Race, Culture and the Colonization of Childbirth in Northern Canada," *Social History of Medicine* 10, no. 3 (1997): 383–400. Maureen Lux argues that immigrant women gratefully sought the help of aboriginal midwives on the Prairies into the 1930s. *Medicine That Walks*, 97–8.
79. For an example of gendered care, see Nancy K. Bristow, " 'You can't do anything for influenza': Doctors, Nurses and the Power of Gender during the Influenza Pandemic in the United States," in *The Spanish Influenza Pandemic of 1918–19: New Perspectives*, ed. Howard Phillips and David Killingray (London: Routledge, 2003), 64.
80. Mitchinson, *Giving Birth*, 30, citing Elaine Leslau Silverman, *The Last Best West: Women on the Alberta Frontier, 1880–1930* (Montreal: Eden Press 1984), 66.
81. Jeffrey Baker, *The Machine in the Nursery: Incubator Technology and the Origins of Newborn Intensive Care* (Baltimore: Johns Hopkins University Press, 1996).
82. Mitchinson, *Giving Birth*, 81. For more on the history of midwifery, see Task Force on the Implementation of Midwifery, "A History of Midwifery in Canada," in *Report of the Task Force on the Implementation of Midwifery in Ontario* (Toronto: 1987); J. T. H. Connor, " 'Larger Fish to Catch Here than Midwives': Midwifery and the Medical Profession in Nineteenth-Century Ontario," in *Caring and Curing*, ed. Dodd and Gorham, 103–34; Suzann Buckley, "Ladies or Midwives? Efforts to Reduce Infant and Maternal Mortality," in *A Not Unreasonable Claim: Women and Reform in Canada, 1880s to 1920s*, ed. Linda Kealey (Toronto: Women's Press, 1979), 131–49; Cecilia Benoit, "Mothering in a Newfoundland Community: 1900–1940," in *Delivering Motherhood: Maternal Ideologies and Practices in the 19th and 20th Centuries*, ed. Katherine Arnup et al. (London: Routledge, 1990), 173–89; Helene Laforce, "The Different Stages of the Elimination of Midwives in Quebec," in *Delivering Motherhood*, ed. Arnup et al., 36–50. For a historiographic review of midwifery in the United States, see Judy Barret Litoff, "Midwives and History," in *Women, Health and Medicine in America*, ed. Rima Apple (New York: Garland, 1990), 443–58.
83. Akito Matsuki, "A Chronology of the Very Early History of Inhalation Anaesthesia in Canada," *Canadian Anaesthesia Society Journal* 21, no. 1 (January 1974): 94.
84. For more on "twilight sleep," see Judith Walzer Leavitt, "Birthing and Anesthesia: The Debate over Twilight Sleep," *Signs* 6, no. 1 (1980): 147–64; Margarete Sandelowski, *Pain, Pleasure, and American Childbirth: From the Twilight Sleep to the Read Method, 1914–1960* (Westport, Conn.: Greenwood Press, 1984).
85. Wesley Bourne, "Analgesia and Anaesthesia in Obstetrics: Pentothatl Sodium, Cyclopropane and Vinyl Ether," *British Journal of Anaesthesia* 15, no. 1 (October 1937): 4–5.
86. George S. Morgan, S. G. Eaman, and Harold R. Griffith, "Cyclopropane Anaesthesia for Caesarean Section: A Comparative Analysis of Two Hundred Cases," *Anaesthesia and Analgesia* 16 (1937): 113.
87. Mitchinson, *Giving Birth*, 57.
88. Ibid., 235, 239. Using the specific example of the debate about performing craniotomies, Judith Walzer Leavitt examines how physicians and hospitals significantly increased their involvement in childbirth. See "The Growth of Medical Authority: Technology and Morals in Turn-of-the-Century Obstetrics," in *Women and Health in America*, 2nd ed., ed. Judith Walzer Leavitt (Madison: University of Wisconsin Press, 1999), 636–58.
89. Mitchinson, *Giving Birth*, 223–4.
90. Ibid, 217.

91. M. E. Kelm, *Colonizing Bodies: Aboriginal Health and Healing in British Columbia, 1900–1950* (Vancouver: UBC Press, 1998), 86–7, 90. For other studies of aboriginal ideas of health and disease, see Lux, *Medicine That Walks*, esp. 71–137; James B. Waldram, D. Ann Herring, and T. Kue Young, *Aboriginal Health in Canada: Historical, Cultural and Epidemiological Perspectives* (Toronto: University of Toronto Press, 1995), chap. 5. For some description of aboriginal practices around childbirth, see Patricia Jasen, "Race, Culture, and the Colonization of Childbirth in Northern Canada," *Social History of Medicine* 10 (1997): 383–400. The literature on aboriginal concepts of health and disease is not extensive compared to studies of the impact of assimilation and racialized and gendered medical ideas. See, for instance, Mary Jane McCallum, "The Last Frontier: Isolation and Aboriginal Health," *CBMH* 22, no. 1 (2005): 103–20.
92. Kelm, *Colonizing Bodies*, 95.
93. Marni Elizabeth Davis, "Southern Kwakiutl Medicine" (MA thesis, University of Victoria, 1977), 5.
94. Kelm, *Colonizing Bodies*, 88.
95. For a description of aboriginal herbal remedies, see J. K. Borchardt, "Native American Drug Therapy: United States and Canada," *Drug News & Perspectives* 16, no. 3 (April 2003): 187–91.
96. Kelm, *Colonizing Bodies*, 96.
97. Ibid., 93–4.
98. Ibid., 92.
99. Ibid., 93.
100. Lux, *Medicine That Walks*, 75.
101. Mitchinson, *Giving Birth*, discusses this concept for Western medicine, 22.
102. Kelm, *Colonizing Bodies*, 158.
103. A point made frequently by Pat Sandiford Grygier, *A Long Way from Home: The Tuberculosis Epidemic among the Inuit* (Montreal: McGill–Queen's University Press, 1994).
104. Kelm, *Colonizing Bodies*, xvii, 154–5, 165. The same argument is made in Lux, *Medicine That Walks*.
105. Kelm, *Colonizing Bodies*, 83.
106. Saks, "Medicine and the Counter Culture," 113.
107. Clow, *Negotiating Disease*, xiv.



CHAPTER 6

Prevention and Treatment of Poliomyelitis

Prevention and Treatment of Poliomyelitis

During the first half of the twentieth century, poliomyelitis (commonly shortened to "polio") was feared as the crippling, sometimes fatal, disease that threatened children, adolescents, and young adults each summer. What was once an endemic, relatively harmless, widespread gastrointestinal infection developed into a threatening paralytic disease that became epidemic in industrialized nations. Canada experienced severe polio outbreaks from the 1920s through to the 1950s.[1] Parents, understandably anxious, were told to be on constant alert for any telltale signs such as sore throat, fever, headache, or stiff neck. Medical scientists struggled to understand the cause of polio, public health officials tried to contain its spread, and the medical community experimented with methods to treat and to cure polio sufferers. Polio was a disease that gave rise to new technologies and therapies, and in Canada, polio outbreaks prompted an unprecedented government response to ensure the provision of treatment to polio sufferers. Yet despite technological innovations and Canadian government initiatives, a cure for polio remained elusive.

Disease Description and Incidence

Polio is a contagious disease caused by three closely related strains of a human enterovirus. Identified in 1909, the poliovirus enters the body through the mouth by ingestion or inhalation. It multiplies in the gastrointestinal tract and invades the lymphatic system, producing swelling in the lymph nodes surrounding the intestine and in the neck. The poliovirus is excreted in the feces of infected persons and spread to uninfected persons through contaminated water; through contact with food, hands, and eating utensils; and by flies and other insects. In the majority of polio cases, infection is confined to the throat and intestine, with viral infection of the nerve cells of the spinal cord and brain stem reported in only a small proportion of cases.

Symptoms vary according to the course of the poliovirus. If the virus does not spread beyond the lymph nodes, the infected person may experience no symptoms at all or minor symptoms of headache, sore throat, and a fever. These complaints may subside in a few days after the body's immune system begins producing antibodies to overcome the virus. The majority of polio cases do not advance beyond this. In a minority of cases, the poliovirus passes through the lymph system, enters the bloodstream, then enters the central nervous system, affecting the nerve cells responsible for stimulating contraction of muscles. More severe symptoms may then emerge, including pain and stiffness in the spine, lethargy, general muscular weakness, and paralysis of muscles (legs, arms, back, thorax, and diaphragm). It is possible for partial or total respiratory paralysis to occur. In the most severe cases, viral infection spreads from the spinal cord to the brain stem, attacking neurons serving the diaphragm and esophagus.

With physical therapy, many polio sufferers may reverse their paralysis, regaining some lost motor function. However, the body cannot replace destroyed neurons or nerve cells, leaving the acute polio sufferer with permanent motor impairment ranging from mild muscular weakness to crippling disability. The emergence of post-polio syndrome in the 1980s and 1990s (as survivors of the 1940s and 1950s polio epidemics matured into middle age) brought reoccurring symptoms of muscle weakness and loss of function for many earlier polio sufferers.[2]

Polio was an endemic disease in the late nineteenth and early twentieth centuries that reached epidemic proportions in the early to mid-twentieth century. Epidemiologists suggest that improved sanitation contributed to polio epidemics. Before 1900, most individuals were exposed to polio at an early age; they contracted the disease but remained symptomless while developing antibodies. Only a minority of polio cases resulted in paralysis. The disease was referred to as infantile paralysis by the medical profession because they viewed it as a children's disease. As sanitation improved in North America and Europe, the chances of contracting polio in early childhood decreased. Older children and adults began contracting the disease and epidemics occurred. Polio tended to cause more severe illness in an adult than in a young child. Today medical scientists suggest that better sanitation, then, meant less exposure, lower immunity levels, and increased susceptibility at older ages.[3]

In Canada, annual outbreaks in the first half of the twentieth century increased from a few hundred cases to a record high of 8,800 cases in 1953.[4] Worldwide, Canada was one of the hardest hit countries, with major epidemics of polio spreading from western to eastern provinces in 1927–28, 1936–37, 1941–42, 1946–47, 1952–53, 1953–54, and 1959–60.[5] The

provinces of Alberta, Manitoba, Ontario, and Quebec recorded a particularly high number of polio cases. Comparatively, Canadian outbreaks coincided with international trends, although earlier epidemics were reported in Scandinavia and the United States. One of the most devastating epidemics in the history of polio occurred in 1916 in the northeastern United States, which reported 9,000 acute cases in New York City alone.[6] What emerged in Canada was a tremendous public health response to fight polio — both its immediacy as a disease claiming lives and its hoped-for future eradication.

The history of the prevention and treatment of polio illustrates the medical profession's changing understanding of this disease. At the turn of the century, the role of micro-organisms in infectious disease was well established. Viruses were still poorly understood, although the medical profession agreed that they were transmissible agents.[7] As an increasing number of polio outbreaks were reported around the world (including Canada, the United States, Switzerland, England, Wales, Australia, and three Scandinavian countries), a variety of measures were implemented, including (1) prevention strategies of quarantine and an experimental nasal spray; (2) therapies attempted to treat and to cure polio; and (3) development of a vaccine.

Prevention: Quarantine and a Nasal Spray

During the polio outbreaks of the 1910s and 1920s, public health authorities attempted to enforce the isolation of critically ill patients and restricted travel of family members in an effort to contain the epidemic. These responses were as ineffective as they had been in the face of most other infectious diseases.[8] The problem was that infected individuals with mild or no symptoms were still able to transmit the disease to others. Fly eradication campaigns also failed, and flies remained another source of transmission.[9] Nevertheless, public health authorities continued to advocate rigid quarantine measures in the hopes of containing the outbreak. Their efforts to control the movements of the infected also extended to the uninfected.

In Toronto and other Canadian cities, public health authorities called for the delay, closure, even cancellation of many public activities for children in an effort to curb further transmission of the disease. Public pools, parks, and theatres were closed, church services and activities cancelled, and school openings delayed to reduce public gatherings and limit contact among children. During the 1937 polio epidemic, public health authorities lobbied for the cancellation of Children's Day at the Canadian National Exhibition (CNE) in Toronto. Smaller local fairs across the province had been cancelled or postponed, but the CNE committee and city officials refused to call off Children's Day. Children did attend the 1937 CNE, though numbers were significantly lower than the previous year.[10]

Public health authorities attempted to control the movements of infected and uninfected children based on their understanding of infectious disease transmission, and also because the medical community had little to offer in terms of treatment for polio. As mentioned, the preventative measures were based on earlier epidemic strategies. In varying degrees, quarantine had been utilized during outbreaks of smallpox, diphtheria, typhoid fever, and influenza.[11] It was a policy of last resort — an attempt to prevent further outbreaks and thus to contain the spread of a disease.

Unique to polio, an experimental nasal spray as a preventative was explored in the United States and Canada in the 1930s. Medical researchers were still grappling with the question of the actual transmission of the poliovirus. One theory was that the virus entered the body through the nose. As a means of prevention, a nasal spray was developed to block the ingestion of the poliovirus. Nasal spray field trials were undertaken in Alabama, Manitoba, and Ontario. Words of caution were mixed with pronouncements that the spray was safe and promising as a polio preventative. Despite the hopes of the medical community and desperate parents, the nasal spray proved ineffective. Several children in both the control group and the nasal spray group contracted polio. Some children who participated in the field trial suffered a permanent loss of smell as a result of the spray. The nasal spray represented one of many experimental therapies introduced to prevent or treat polio. Shortly after the failed field trials of the 1930s, the medical community's understanding of polio began to shift: it was no longer classified as a nasal but as an intestinal disease.[12]

To Treat and to Cure: Convalescent Serum, Respirators, Bed Frames, and Splints

In an effort to treat and to cure polio, a number of therapies were tried that produced mixed results, demonstrating the medical community's struggle to understand the disease and to relieve polio sufferers. By the early decades of the twentieth century, medical laboratories provided antitoxins for diphtheria, rabies, and tetanus; vaccines for plague, cholera, yellow fever, and typhoid; and diagnostic tests for tuberculosis, diphtheria, typhoid, and several venereal diseases.[13] As argued by Peter Twohig, "In 1909 the poliovirus was identified and, following the course of other discoveries, clinicians and the public alike believed that the laboratory would soon provide a way to identify those

infected and, more importantly, a treatment."[14] This expectation led to the preparation and distribution of a blood serum from individuals who had recovered from the disease — which was the dominant treatment for polio from the 1920s to the 1940s.

The gamma globulin from the recovered polio patient (blood proteins with the antibodies against polio) was incorporated into what was called a convalescent serum. This convalescent serum was then injected into the acute polio sufferer to help fight the disease.[15] Gamma globulin had worked for other diseases, such as hepatitis; however, it did not work at all in the case of polio. The level of antibodies in the serum was not high enough to have a therapeutic effect. Despite disappointing results, the medical community was unwilling to abandon serum therapy for several decades.[16]

Mechanical respirators or iron lungs provided some hope of survival to polio patients in respiratory failure. Patients with spinal or bulbar polio suffered paralysis of the diaphragm due to nerve damage along the upper spinal cord and/or the brain stem. In 1928, Philip Drinker and Louis Shaw of the Harvard School of Public Health in Boston, Massachusetts, designed and constructed the first electrically powered tank respirator, an apparatus for long-term artificial respiration.[17] This machine mimicked the action of the lungs (inspiration and expiration of air) by applying negative pressure on the chest, forcing the lungs to expand and collapse. The patient was fully enclosed within the respirator, lying on their back with only their head protruding from the steel machine. A rubber collar fit snugly around the patient's neck to form a tight seal.[18] Nurses required specialized training to regulate the machine and to care for the patient inside the tank.[19] It was a terrifying experience for those who spent time in an iron lung. Patients often felt isolated, even trapped in their prone positions in these machines, despite personalizing their space with stuffed animals, flowers, mirrors, and radios.[20]

In the United States, tank respirators were manufactured by the W. E. Collins Company and J. H. Emerson Company in the 1930s, and later by Fabrikator Inc. in the 1950s. From England, William Morris, later Lord Nuffield, assembled iron lungs in his automobile factory, Morris Motors, and donated them to any hospital in the Commonwealth that wanted one in the late 1930s. In 1938, Canada received a total of 279 Nuffield lungs — each province and territory received at least one Nuffield lung, with Ontario hospitals receiving the largest number.[21] There were no commercial manufacturers of respirators in Canada. Canadian hospitals purchased American-built respirators and occasionally constructed their own "homemade" iron lungs. At the Children's Memorial Hospital in Montreal in 1931, and again in 1937 at Toronto's Hospital for Sick Children, wooden lungs (respirators) were built as emergency responses to save the lives of polio victims in respiratory failure.[22] In each case, the patient survived but the wooden lungs were inferior to the steel respirators.[23] In the throes of a polio epidemic in 1937, the city of Toronto was unable to purchase any American commercial respirators. The Ontario provincial government thus contracted Toronto's Hospital for Sick Children (HSC) to build 27 steel respirators in their hospital workshop for distribution throughout the province.[24] These HSC-built iron lungs were used successfully in many cases in Ontario and neighbouring provinces.[25]

Figure 29. *Hospital staff constructing steel tank respirators in the basement of Toronto's Hospital for Sick Children in 1937. These "homemade" iron lungs were used successfully in many cases, but were soon replaced by American commercial models.*

(Toronto's Hospital for Sick Children Archives)

Polio patients suffering from partial respiratory failure may not have required an iron lung but did utilize other equipment designed to assist breathing, including rocking beds and cuirass respirators. The rocking bed was a lesser respiratory aid that produced artificial respiration by passive motion of the diaphragm in the shifting of the abdominal organs. Rocking was not used for more than eight hours a day, so it was appropriate only for those who needed breathing help on a temporary basis.[26] The cuirass or chest respirator (an iron lung writ small) only

partially encased the patient — typically extending from the patient's armpits to the pelvis — and provided some pressure upon the chest to assist breathing.

There are numerous examples of "homemade" chest respirators designed and built during the 1937 epidemic in Ontario. At the University of Toronto's Banting Institute, Dr Bernard Leibel built ten cuirass respirators — dubbed "Leibel Lungs" — that were used at the Toronto General Hospital. (Later, an American company commercially manufactured this cuirass respirator and paid royalties to the University of Toronto.)[27] At the Toronto General Hospital, Chief Engineer Albert Darbyshire built his own air-driven negative-pressure machine that extended from the patient's neck to the hips. At Toronto's Hospital for Sick Children, Superintendent Joseph Bower created custom-built jacket respirators from plaster moulds of patient chests.[29] By the 1940s, commercial cuirass respirators — now more readily available — replaced "homemade" versions.[30] The cuirass respirator was not as effective as the tank respirator since it was capable of generating only two-thirds of the pressure obtainable in an iron lung. However, it provided greater patient mobility and easier nursing care than the tank respirator, and was utilized for convalescent and chronic respiratory polio patients. Polio patients were weaned from iron lungs to chest respirators to rocking beds whenever possible.

"Homemade" iron lungs were a product of the 1930s epidemic needs. Later outbreaks in the 1940s and 1950s in Canada did not result in the same in-house manufacturing response. By this time, American and British commercial respirators had been significantly refined, offering more features than any crude homemade model, and respirator companies were able to keep up with demand. By the late 1950s, early homemade respirators disappeared entirely from provincial registry lists.[31] Also by this time, both cuirass and tank respirators fell into general disuse as a form of respiratory therapy in favour of newer treatment based on the principle of intermittent positive pressure ventilation (IPPV), utilized in Copenhagen in a 1953 polio epidemic. IPPV can be achieved by hand ("bagging") or by tracheotomy to force air into the patient's airways to simulate inhalation and exhalation of the lungs. In cases of obstructed airways, negative pressure ventilation (as in the iron lung) did not work, whereas IPPV did. Copenhagen doctors treated hundreds of bulbar patients successfully with IPPV, thereby refining many of the principles of IPPV for adoption elsewhere for treating polio patients in respiratory failure. IPPV also marked the beginning of respiratory intensive care.

Did the iron lung save lives? This depended on the type of polio contracted. The iron lung was not a cure for respiratory polio patients. It bought the patient time for the body to rest and fight the paralysis by providing a form of artificial respiration. It addressed the symptoms but not the cause of the disease. The respirator was most effective in treating spinal polio, or intercostal paralysis, when the machine replaced the function of the intercostal muscles, allowing them to rest and ultimately recover. The patient could then be removed from the respirator. The machine was not effective in cases of bulbar polio, when the nerve cells in the breathing centre of the brain were irreversibly damaged. No amount of rest by treatment in a respirator would allow for nerve regeneration and disappearance of paralysis.[32] Despite this knowledge, physicians often placed all polio patients in respiratory failure in the iron lung. They hoped that it might work; the alternative, acceptable neither to families nor to attending doctors, was to do nothing while the patient died. This pattern led to the overuse of the iron lung (utilized often as a treatment of last resort). Before the iron lung, mortality from respiratory polio was 100 percent. With the iron lung, the mortality rate was still greater than 50 percent. In the case of the 1937 Ontario polio

Figure 30. *The mirror attached to this iron lung increased this polio patient's range of vision; in other cases an affixed book rack enabled patients to read. Such measures were attempts to combat the isolation and confinement of patients in these machines.*
(City of Vancouver Archives, CVA 1184-2747)

epidemic, the numbers were higher — approximately two-thirds of those who went into an iron lung did not come out alive.[33]

With the onset of paralysis in the legs and arms, polio sufferers were immobilized and put on bed rest. Orthopedic treatments included bracing, splinting, and/or casting with elaborate pulley systems to immobilize limbs. In Canada, many paralytic polio patients were strapped to a "Bradford Frame," a rectangular frame with canvas lacing and attached arm and foot splints. Standardized splints and frames were built at Toronto's Hospital for Sick Children, the Hamilton General Hospital, and London's Victoria Hospital, and distributed throughout the province at the government's expense. The 150-bed Ontario Orthopedic Hospital opened in 1937 and was exclusively a paralytic polio children's hospital that effectively treated hundreds of patients.[34] Some practitioners nonetheless challenged the dominant treatment of immobilization and bed rest. Most notably, Sister Elizabeth Kenny (1886–1952), an Australian nurse, spoke out against immobilization and instead advocated a program of active massage, moist heat, and passive exercise in acute paralytic polio cases.[35] Her unconventional methods found a following in Canada, the United States, and Great Britain as well as in Australia. Sister Kenny's treatment challenged the medical orthodoxy and offered the public a gentler alternative.[36] Her aggressive physical therapy approach contributed to changes in polio aftercare and rehabilitation medicine in general.[37]

Development of a Vaccine

From the 1920s, medical researchers sought to develop a vaccine against polio.[38] They understood that an attack of polio, regardless of severity, confers lifelong immunity. Although not a cure, a polio vaccine would protect against future outbreaks. Vaccines rely on dead or non-virulent strains of a pathogenic agent to induce an immune response in the host. After several failed attempts, the American virologist Jonas Salk (1914–1995) developed an inactivated, injectable vaccine against polio in 1953.[39] The Salk vaccine was tested in 1954–55 in the United States and Canada on first-, second-, and third-grade schoolchildren. The double-blind field test results demonstrated that the Salk vaccine was safe and successful; it confirmed that the dead virus could not cause the disease but conferred polio immunity. However, the tragic exception was the Salk vaccine lot produced by Cutter Laboratories in California, which still contained the live virus, thus inadvertently infecting American children, of whom many contracted paralytic polio.[40] This case was ruled as a laboratory error in manufacturing the vaccine. The Salk vaccine was heralded as a great contribution.[41]

The University of Toronto's Connaught Medical Research Laboratories played a significant role in cultivating enough quantities of the Salk vaccine for the 1954–55 field test.[42] Connaught researchers developed Medium 199, a synthetic nutrient base in which to cultivate the poliovirus in monkey kidney cells. Medium 199 provided a non-allergenic base for vaccine production, thus making it viable for human use. A second innovation emerged with the decision to cultivate the poliovirus in large bottles that were kept in gentle motion in specially designed electric cradles. Medium 199 and the rocking bottles technique allowed the laboratory to produce bulk quantities of the poliovirus. Connaught produced approximated 3 000 litres of poliovirus fluids. These were sent to various American pharmaceutical companies, such as Parke Davis in Detroit and Eli Lilly in Indianapolis, for preparation as a finished vaccine for the Salk vaccine field trial.[43] Connaught went on to prepare its own finished Salk vaccine for testing on Canadian schoolchildren in April 1955. The Canadian field test of the Salk vaccine proved successful.

Figure 31. *Connaught Laboratories produced about 3 000 litres of poliovirus fluids, which were sent to various American pharmaceutical companies for preparation as a finished vaccine for the Salk vaccine field trial in 1954–55.*
(Reprinted with permission from Sanofi Pasteur Ltd. [Connaught Campus], Toronto)

Nevertheless, the Salk vaccine required multiple shots and an annual booster for the recipient to maintain immunity; this shortcoming motivated other researchers to develop a better vaccine. The American virologist Albert Sabin (1906–1993) developed an oral, live-virus vaccine that offered permanent immunity to children. Instead of by injection, the Sabin vaccine could be taken by mouth on a sugar cube. A more practical vaccine option for developing countries, the Sabin vaccine was tested by the World Health Organization in field trials in fifteen countries that reported successful results.[44] In the early 1960s, the Sabin vaccine supplanted the Salk vaccine as the vaccine of choice in many countries.[45] In Canada, Connaught produced both the Salk inactivated injected vaccine (IPV) and the Sabin attenuated live oral vaccine (OPV), both of which were highly effective. Some provinces and territories used only one vaccine exclusively while others adopted a combination approach of using both. By the late 1990s, Connaught developed an improved polio (eIPV) vaccine through a pentavalent combination product, Pentacel(tm), which has since been adopted across Canada.[46]

Public and Government Response to Polio

By the 1930s, a "war on polio" had emerged, with the Canadian public and government joining forces in a campaign to contain the outbreaks and to support therapies for polio sufferers. During the polio season (June to September), Canadian newspapers printed the number of reported cases; described the symptoms of the disease to anxious parents; announced the pool, theatre, and school closings; and celebrated the success stories of children's lives saved. The media played a key role in shaping public perception of polio epidemics.[47] They reported on how the outbreak was being handled by public health officials, the medical profession, and the community. For example, newspapers celebrated the heroic efforts of staff at Toronto's Hospital for Sick Children to build steel respirators (iron lungs) that saved some children. *Maclean's Magazine* ran a story entitled "Iron Lungs: The Thrilling Story of How a Canadian Hospital Won a Desperate Race with Death by Building Its Own Polio Lungs," and *Saturday Night* magazine printed a report entitled "War on Polio Speeds Up Iron Lung Production."[48] The language adopted — the war against polio — resonated in a century in which Canadians had faced a world war and soon would face another. It rallied public support to work together to fight this children's disease. It represented a way of constructing disease that had emerged earlier with tuberculosis campaigns and would continue with campaigns to eradicate cancer and heart disease.

Several high-profile personalities lent their leadership and resources to the polio campaign. In the United States, Franklin Delano Roosevelt was stricken in 1921 with acute paralytic polio that left him with severe paralysis of both legs.[49] Roosevelt established a centre for the rehabilitation of polio victims in Warm Springs, Georgia, where he himself sought treatment.[50] After Roosevelt became president, he used the president's Birthday Ball Commission as a charitable organization structure to raise money for polio research and treatment. This was the forerunner to the National Foundation for Infantile Paralysis (NFIP), which Roosevelt inaugurated in 1938. The NFIP was a national charity that undertook a massive public relations crusade.[51] Its focus was the March of Dimes fundraising campaign, which asked the public to send a dime directly to the White House to help fight polio. This money supported medical research as well as treatment costs for polio sufferers. Throughout the United States, mothers marched and canvassed neighbourhoods to collect dimes, while celebrities including Judy Garland, Jimmy Stewart, Robert Young, and others made public service announcements.[52] The March of Dimes became a symbol of the power of small contributions ordinary people could make towards the war on polio.

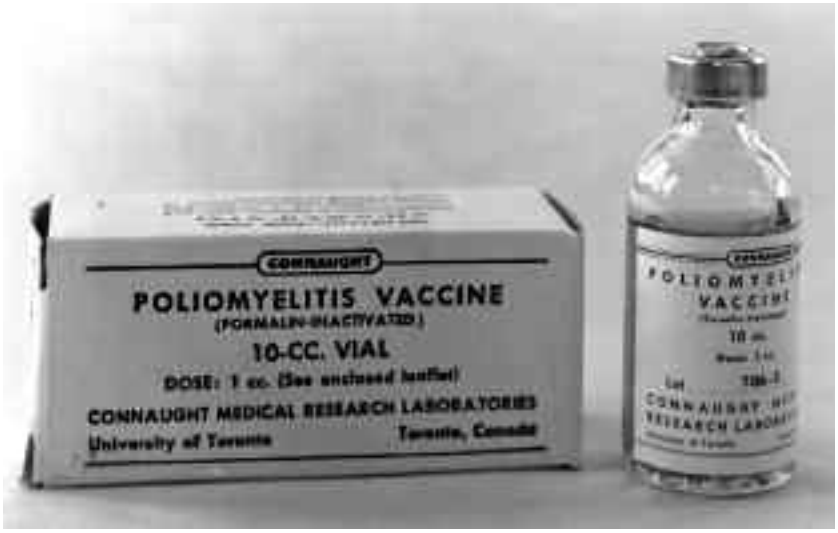


Figure 32. *In Canada, Connaught Laboratories manufactured and distributed the Salk vaccine, an inactivated (dead) injected vaccine used to maintain immunity against poliomyelitis.*

(Reprinted with permission from Sanofi Pasteur Ltd. [Connaught Campus], Toronto)

In Canada, March of Dimes chapters were organized by the Canadian Founda-

tion for Poliomyelitis (CFP) with similar emphasis on volunteerism and celebrity endorsement to raise awareness and funding. The Marching Mothers canvassed door to door to raise funds for polio research, notably vaccine research in the early 1950s. Canadian homes left their porch lights on to signal their support of the March of Dimes fundraising campaigns.[53] Yet, as noted by Christopher Rutty, the CFP played a smaller role than its American counterpart due to political tensions with other voluntary organizations and provincial government programs already serving the needs of polio sufferers. As a result, the CFP focused its support on rehabilitation treatment and care for recovering polio patients.[54]

In contrast to the emphasis on the individual and on philanthropic societies in all phases of the fight against polio in the United States, the Canadian response to handling the polio epidemics and aftercare came from governments. Local, provincial, and federal governments assumed responsibility for polio prevention and treatment with the full co-operation of the medical profession and the public's gratitude. Physicians and families of polio sufferers faced great frustration and financial challenges in combatting and treating this disease. The provinces of Alberta, Ontario, Manitoba, and Saskatchewan led the way with new policies, facilities, equipment, and funding for polio prevention and treatment programs.[55] In 1937, the Ontario government underwrote all costs relating to the prevention, diagnosis, and treatment of polio, including the construction and distribution of respirators and orthopedic equipment and the treatment and hospital stays of polio sufferers.

Despite this help, the financial burden faced by the family could be overwhelming, as expressed by one mother whose child died despite being placed in an iron lung. To the Ontario premier Mitchell Hepburn she wrote: "You will have some idea of the expense, what with three special nurses every 24 hours and the hospital fees added to this, to say nothing of the funeral. And added again to the funeral was the hermetically sealed coffin case which the Government demanded and which cost us $50."[56] The acceptance of financial responsibility by the provincial government for all polio patients was a significant gesture; many families of polio victims faced economic disaster when confronted with hospital bills, doctors' fees, and special nursing costs. This government assistance signalled a marked expansion in state medicine in ensuring access to medical services for its citizens.[57]

After the Second World War, government support for polio research and treatment expanded. In Ottawa, Paul Martin Sr, Minister of National Health and Welfare under Prime Minister Louis St Laurent, took particular interest in funding polio initiatives. Martin had been stricken with polio as a child in 1907, as had his son Paul Martin Jr in 1946.[58] Martin was instrumental in supporting the Canadian Foundation for Poliomyelitis (or March of Dimes) and its efforts to fund polio research and provide medical and rehabilitative assistance to polio sufferers. In the early 1950s, the Dominion Council of Health took action to compile an equipment registry list. It was hoped that such a registry list would be useful to provincial health authorities and hospitals to locate equipment when needed to combat polio outbreaks.[59] Martin's greatest contribution may have been his commitment to the Salk vaccine field trial in Canada in 1955 and his refusal to cut short the inoculation of Canadian schoolchildren despite political pressure to do so in response to the American controversy surrounding the bad Cutter laboratories vaccine lot. Martin's faith in the Salk vaccine lots produced by Connaught Laboratories (Canada's sole source for the field trial) was rewarded with a "100% successful" result. Both the Salk and Sabin vaccines,

Figure 33. *A polio patient reads the newspaper headline announcing the development of the polio vaccine. Unlike the tank respirator or iron lung, which encapsulated the entire body, the cuirass or chest respirator typically extended from the patient's armpits to the pelvis. This provided greater patient mobility and easier nursing care but could generate only two-thirds of the pressure of an iron lung.*

(March of Dimes Canada archives, www.marchofdimes.ca)

deservedly celebrated breakthroughs, contributed to the prevention of future polio epidemics. A cure for polio, however, has still not been found.

Conclusion

The case of polio highlights several trends in twentieth-century medicine. First, the medical community's understanding of disease etiology and ability to treat (not simply diagnose) disease expanded. By mid-century, the medical community had a better understanding of the cause of polio as well as an effective means to control (not cure) the disease. Once polio was defined as a viral disease, medical authorities employed strategies of quarantine and isolation to contain polio, as had been the strategy in past infectious disease epidemics. Experimental strategies of prevention and treatment led to further knowledge of the disease.[60] By the 1930s (after the nasal spray field trials), the medical community's understanding of polio shifted from classifying it as a nasal infection to an intestinal disease. From the 1930s to the 1950s, treatments including respirators, immobilization, and moist heat were used to treat the symptoms of polio. A preventative vaccine was then developed, which has been successfully employed since the mid 1950s to control the disease.

Second, there was growing if tempered optimism in the possibility of new technological solutions to old medical problems during this period. Polio gave rise to new technologies, experimental and unconventional therapies, and a much-welcomed vaccine. Nasal sprays, iron lungs, cuirass respirators, rocking beds, braces, splints, and poliovirus vaccines were technologies that sought to prevent polio outbreaks or to treat paralytic polio sufferers. The iron lung symbolized the severity of the polio epidemics and elicited both hope and fear in the public. Polio sufferers and their families hoped this technological innovation would relieve their paralysis but feared that death would be their only release from an iron lung incarceration. *Life* magazine included a picture of the iron lung in their portrayal of the 100 events that shaped America.[61] Referred to as a "half-way technology" by some academics, the iron lung treated the effects of the disease but not the disease itself, and as a result the iron lung was not always successful.[62] The March of Dimes continues to showcase the iron lung often during its fundraising drives not to celebrate the technological success of the respirator, but as a reminder of the crippling and fatal effects of polio and technology's confinement of, and sometimes inability to save, the patient. The public celebrated the Salk and Sabin vaccines as the best weapons against polio and as safeguards against the iron lung. Just as the iron lung should be celebrated as a technological advancement as a successful artificial diaphragm, it should also be a reminder of the limitations of technological capabilities. Society's reluctant acceptance of the iron lung rested on a widespread belief in technology's power to cure. In the case of polio, technology failed.

Third, the state increasingly played a greater role in health care management, specifically shifting the costs of treatment from the individual to the state. In Canada, polio outbreaks prompted an unprecedented government response to ensure the provision of treatment to polio sufferers. The provincial governments of Alberta, Saskatchewan, Manitoba, and Ontario enacted generous polio policies, funding treatment programs and hospital stays. The acceptance of financial responsibility by provincial governments for polio patients was a significant gesture. It signalled a marked expansion in state medicine in ensuring citizens' access to medical services.

Fourth, the public, the government, and the medical community joined together to fight disease. Like earlier tuberculosis campaigns, a "war on polio" was declared that enlisted medical researchers, practitioners, public health authorities, government officials, benevolent societies, the media, mothers, fathers, and the general public to do their part towards containing (hopefully eradicating) the disease. This campaign encompassed awareness, education, medical treatment, and fundraising such as the March of Dimes activities. Medical reporting by the media remained triumphant for breakthrough treatments and highlighted stories of patient recovery. The campaign developed to fight polio thereafter shaped the response of Canadian society and science to many other diseases — such as cancer, heart disease, and AIDS — that became predominant in the second half of the twentieth century.

Notes

1. Although not as severe as later epidemics, Canada's first significant outbreak of polio occurred in 1910. Dr Helen MacMurchy, the child welfare advocate, drew the Canadian public's attention to the disease in her article "Paralysis: The New Epidemic," *Maclean's* (November 1912): 110. Cited in Christopher J. Rutty, Luis Barreto, Rob Van Exan, and Shawn Gilchrist, "Conquering the Crippler: Canada and the Eradication of Polio," *Canadian Journal of Public Health* 92, no. 2, insert (March/April 2005): I-4. See also Dianne Dodd, "Advice to Parents: The Blue Books, Helen MacMurchy, MD and the Federal Department of Health," *CBMH* 8, no. 2 (1991): 203–30.
2. John R. Paul, *A History of Poliomyelitis* (New Haven, Conn.: Yale University Press, 1971), 1–8. For more on polio etiology, see J. I. P. James, *Poliomyelitis* (London: Edward Arnold, 1987); John N. Walton, *Diseases of the*

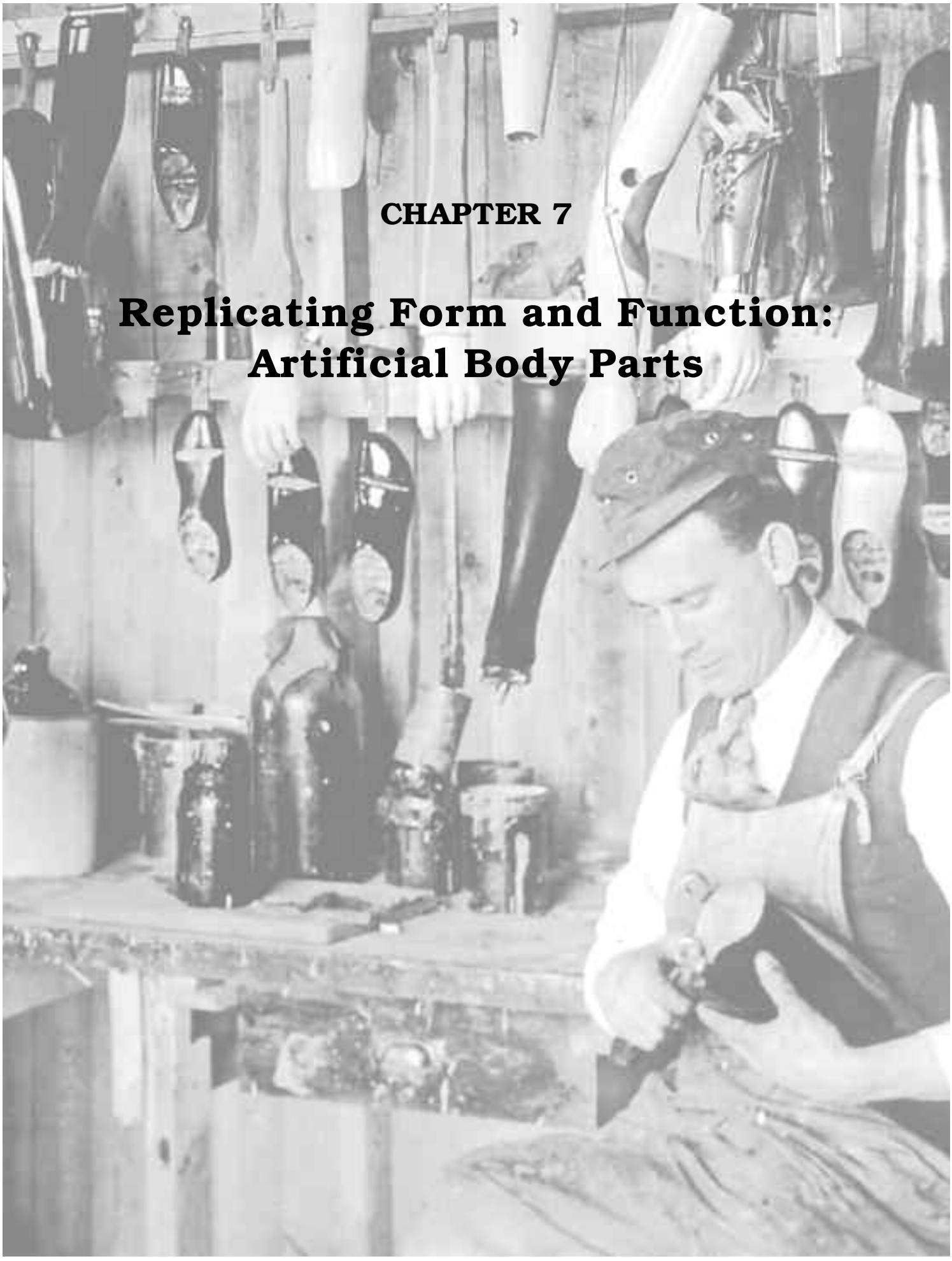
Nervous System, 9th ed. (Oxford: Oxford University Press, 1985); V. C. Vaugh and R. E. Behrman, *Textbook of Pediatrics*, 12th ed. (Philadelphia: W. B. Saunders, 1983); and Lauro S. Halstead and Gunnar Grimby, eds., *Post-Polio Syndrome* (St Louis: Mosby, 1995).

3. See Harry F. Dowling, *Fighting Infection: Conquests of the Twentieth Century* (Cambridge, Mass.: Harvard University Press, 1977); William Beatty and Geoffrey Marks, *Epidemics* (New York: Scribner, 1976); Paul, *History of Poliomyelitis*; Thomas M. Daniel and Frederick C. Robbins, "A History of Poliomyelitis," in *Polio*, ed. Thomas M. Daniel and Frederick C. Robbins (New York: University of Rochester Press, 1997), 5–22.
4. Jacalyn Duffin, *History of Medicine* (Toronto: University of Toronto Press, 1999), 161.
5. Christopher J. Rutty, "The Middle-Class Plague: Epidemic Polio and the Canadian State, 1936–37," *CBMH* 13, no. 2 (1996): 284; Rutty et al., "Conquering the Crippler," I-3. See also Christopher J. Rutty, "Do Something! Do Anything! Poliomyelitis in Canada, 1927–1967" (PhD thesis, University of Toronto, 1995).
6. Stuart Galishoff, "Newark and the Great Polio Epidemic of 1916," *New Jersey History* 94 (1976): 101–11.
7. Michael B. A. Oldstone, *Viruses, Plagues and History* (New York: Oxford University Press, 1998), chap. 7, "Poliomyelitis," 90–115.
8. As noted in chapter 1, in the case of influenza in 1918, for example, the lack of any reliable diagnostic test made quarantine measures ineffectual. Esyllt W. Jones, " 'Co-operation in All Human Endeavour': Quarantine and Immigrant Disease Vectors in the 1918–1919 Influenza Pandemic in Winnipeg," *CBMH* 22, no. 1 (2005): 70.
9. Naomi Rogers, *Dirt and Disease: Polio Before FDR* (New Brunswick, N.J.: Rutgers University Press, 1992); Naomi Rogers, "Dirt, Flies and Immigrants: Explaining the Epidemic of Poliomyelitis, 1900–1916," *Journal of the History of Medicine and Allied Sciences* 44 (1989): 486–505. On quarantine, see Linda Ambrose, "Quarantine in Question: The 1913 Investigation at William Head, B.C.," *CBMH* 22, no. 1 (2005): 139–53; Jones, "Co-operation," 57–82.
10. Rutty, "Middle-Class Plague," 289–90. See also Christopher James Rutty, "A Grim Terror More Menacing, More Sinister Than Death Itself: Physicians, Poliomyelitis and the Popular Press in Early 20th Century Ontario" (MA thesis, University of Western Ontario, 1990).
11. See Judith Walzer Leavitt, *Typhoid Mary: Captive to the Public's Health* (Boston: Beacon Press, 1996); Howard Markel, *Quarantine! East European Jewish Immigrants and the New York City Epidemics of 1892* (Baltimore: Johns Hopkins University Press, 1997); Jones, "Co-operation," 57–82; Esyllt W. Jones, *Influenza 1918: Disease, Death, and Struggle in Winnipeg* (Toronto: University of Toronto Press, 2007).
12. Paul, *History of Poliomyelitis*, 250, 382; Rutty, "Middle-Class Plague," 291–5.
13. Peter L. Twohig, *Labour in the Laboratory: Medical Laboratory Workers in the Maritimes, 1900–1950* (Montreal: McGill–Queen's University Press, 2005), 48.
14. Ibid.
15. For a clear description of the preparation process for this convalescent serum, see Twohig, *Labour in the Laboratory*, 48.
16. In Nova Scotia, doubts were raised during the early 1930s regarding the effectiveness of convalescent serum yet it continued to be used. British Columbia also continued to distribute convalescent serum, while skepticism within the Alberta medical community prevented its widespread use. See Twohig, *Labour in the Laboratory*, 49; Rutty et al., "Conquering the Crippler," I-6; Paul, *History of Poliomyelitis*, 190–9.
17. Howard Markel, "The Genesis of the Iron Lung," *Archives of Pediatrics and Adolescent Medicine* 148 (1994): 1174–6; Paul, *History of Poliomyelitis*, 324–34.
18. Medical Research Council, *"Breathing Machines" and Their Use in Treatment*, Report of the Respirators (Poliomyelitis) Committee, Special Report Series 237 (London, 1939).
19. Lynne M. Dunphy, "The Steel Cocoon: Tales of the Nurses and Patients of the Iron Lung, 1929–55," *Nursing History Review* 9 (2001): 3–33.
20. Narrative accounts from those who "survived polio" have been published, including those treated in iron lungs. See Kathryn Black, *In the Shadow of Polio: A Personal and Social History* (Reading, Mass.: Addison-Wesley, 1996); Regina Woods, *Tales from Inside the Iron Lung* (Philadelphia: University of Pennsylvania Press, 1994); Mimi Rudolph, *Inside the Iron Lung* (London: Butler & Tanner, 1984); Jane Smith, *Paralyzing Fear: The Triumph over Polio in America* (New York: TV Books, 1998); Daniel J. Wilson, *Living with Polio: The Epidemic and Its Survivors* (Chicago: University of Chicago Press, 2005); Tony Gould, *A Summer Plague: Polio and Its Survivors* (New Haven: Yale University Press, 1995); Fred Davis, *Passage through Crisis: Polio Victims and Their Families* (New Brunswick, N.J.: Transaction Publishers, 1991).
21. D. W. G. Murray, Papers, RG 29, Vol. 182, File 302-3-1, Library and Archives Canada.
22. Jessie Boyd Scriver, *The Montreal Children's Hospital: Years of Growth* (Montreal: McGill–Queen's University Press, 1979), 86–7. See also A. R. Foley, "The 1932 Epidemic of Poliomyelitis in Quebec," *Canadian Public Health Journal* 25 (1934): 266.
23. In the early 1950s, instructions on how to build an emergency wooden lung were available from the Council on Physical Medicine and Rehabilitation of the American Medical Association as well as *Popular Mechanics*. Both sources claimed that a wooden lung could be easily constructed by a carpenter or cabinet-maker within a few hours from easily obtainable materials in the community. Yet both sources clearly stated that these wooden lungs were pieces of emergency equipment for temporary use until a commercial respirator could be obtained. See Gerald M. Cline, Homer O. Dolley, and Ralph C. Osborn, "Emergency Wooden Respirator," *Journal of the American Medical Association* 145, no. 7 (17 February 1951): 485; "Emergency Wooden Respirator," *Popular Mechanics* (January 1952): 262–7.
24. See Polio File at the Toronto Hospital for Sick Children Archives, which includes photographs, newspaper clippings, a Rotary Club speech by hospital superintendent Joseph Bower, who was involved in the building of the respirators, and "Out of the Iron Lung," an account by a mother whose son was placed in an iron lung at the Hospital for Sick Children. Note that one surviving HSC-built respirator resides in the collections of the Museum of Health Care at Kingston, www.museumofhealthcare.ca.
25. Ontario Department of Health, *Report on Poliomyelitis in Ontario, 1937* (March 1938); "Study of Poliomyelitis Epidemic in Ontario in 1937," *Canadian Hospital* (July 1938): 40. See also "Drinker Respirator Use for First Time in a Canadian Hospital," *Canadian Hospital* (April 1931): 28, 31; Agnes Armstrong, "War on Polio Speeds Up Iron Lung Production," *Saturday Night* (9 October 1937); Rutty, "Middle-Class Plague," 296–8.
26. See George Saxton Jr, "Control of Respiration: B. Technics for Providing Artificial Respiration: Cuirass

Respirators, Rocking Beds, and Portable Respirators," *Poliomyelitis: Papers and Discussions Presented at the Fourth International Poliomyelitis Conference, Geneva, July 15–20, 1957* (Philadelphia, 1958), 498–9.

27. Dr Bernard Leibel, interview with Shelley McKellar, 28 March 1994, Toronto; *Toronto Daily Star* (3 and 4 September 1937); *Toronto Evening Telegram* (4 and 18 September 1937).
28. *Toronto Daily Star* (27 and 29 September 1937); *Toronto Globe and Mail* (27 September 1937).
29. *Toronto Daily Star* (4 October 1937); *Toronto Evening Telegram* (6 October 1937).
30. Announcements of commercial cuirass respirator acceptances placed by the Council on Physical Medicine and Rehabilitation in the *Journal of the American Medical Association* include the Blanchard Portable Plastic Respirator, *JAMA* 137 (3 July 1948): 867; Monaghan Portable Respirator, *JAMA* 139 (30 April 1949): 1273; Chestpirator Portable Chest Respirator (Fabrikators), *JAMA* 141 (5 November 1949): 658; Fairchild-Huxley Chest Respirator, *JAMA* 143 (29 July 1950): 1157; Chestpirator Portable Chest Respirator Jr (Fabrikators), *JAMA* 146 (12 May 1951): 108; Monaghan Hospital Respirator, *JAMA* 149 (16 August 1952): 1473; Respirair Portable Plastic Respirator (Fabrikators), *JAMA* 150 (13 December 1952): 1489.
31. Murray Papers, RG 29, Vol. 34, File 311-P11-27.
32. James L. Wilson, "The Mechanical Respirator in Poliomyelitis," *Journal of Pediatrics* 16 (1940): 467.
33. Exact statistics of those who died in the iron lung can be found in the Ontario Department of Health, *Report on Poliomyelitis in Ontario, 1937* (March 1938), 47. Regarding high mortality rate, see also David Rothman, *Beginnings Count: The Technological Imperative in American Health Care* (New York: Oxford University Press, 1997), chap. 2, "The Iron Lung and Democratic Medicine," 41–66.
34. Special polio hospitals were opened in other Canadian cities, including one in Edmonton in 1927. Rutty, "Middle-Class Plague," 299–302.
35. Paul, *History of Poliomyelitis*, 335–45.
36. Roy Porter states: "There was, in effect, a contest between the medical elite, the maverick Kenny, and the public as to who was to have ultimate say in the authorization of new therapies. It was a political struggle often to be repeated in medicine in the latter half of the twentieth century." *The Greatest Benefit to Mankind: A Medical History of Humanity* (New York: W. W. Norton & Co., 1997), 695.
37. For more on Sister Kenny, see Victor Cohn, "Sister Kenny's Fierce Fight for Better Polio Care," *Smithsonian* 12 (1981): 180–200; Victor Cohn, *Sister Kenny: The Woman Who Challenged the Doctors* (Minneapolis: University of Minnesota Press, 1975); Naomi Rogers, "The Debate Considered [Historians and Sister Kenny]," *Australian Historical Studies* 114 (2000): 163–6; Naomi Rogers, *Healer from the Outback: Sister Elizabeth Kenny, Polio and American Medicine, 1940–1952*, forthcoming.
38. See Margaret L. Grimshaw, "Scientific Specialization and the Poliovirus Controversy in the Years before World War II," *Bulletin of the History of Medicine* 69 (1995): 44–65.
39. See Richard Carter, *Breakthrough: The Saga of Jonas Salk* (New York: Trident Press, 1962); Jeffrey Kluger, *Splendid Solution: Jonas Salk and the Conquest of Polio* (New York: G. P. Putnam's Sons, 2004).
40. See Paul A. Offit, *The Cutter Incident: How America's First Polio Vaccine Led to the Growing Vaccine Crisis* (New Haven: Yale University Press, 2005).
41. See Jane S. Smith, *Patenting the Sun: Polio and the Salk Vaccine* (New York: William Morrow & Co., 1990); Arthur Allen, *Vaccine: The Controversial Story of Medicine's Greatest Lifesaver* (New York: W. W. Norton, 2007).
42. Not surprisingly, due to Connaught's expertise in producing antitoxins, immune serums, vaccines, and insulin, this lab played a significant role in Canada's response to polio. In fact, earlier, during the 1920s and 1930s, Connaught had produced convalescent serum. Rutty et al., "Conquering the Crippler," I-5, I-10.
43. Christopher J. Rutty, "Herculean Efforts: Connaught and the Canadian Polio Vaccine Story," *Contact* 9, no. 3 (June 1996).
44. Saul Benison, "International Medical Cooperation: Dr. Albert Sabin, Live Poliovirus Vaccine and the Soviets," *Bulletin of the History of Medicine* 56 (1982): 460–83.
45. Paul, *History of Poliomyelitis*, 412–25.
46. Rutty et al., "Conquering the Crippler," I-17. See also Bernard Seytre, Mary Shaffer, and Christine Laquenan, *A World without Polio: The Men and Women of Aventis Pasteur in the March of History* (Lyon: Aventis Pasteur, 2003).
47. See Rutty, "Grim Terror." For an examination of the cultural history of polio or the meaning of polio in society, see Marc Shell, *Polio and Its Aftermath: The Paralysis of Culture* (Cambridge: Harvard University Press, 2005).
48. Frederick Edward, "Iron Lungs: The Thrilling Story of How a Canadian Hospital Won a Desperate Race with Death by Building Its Own Polio Lungs," *Maclean's Magazine* (15 January 1938); Armstrong, "War on Polio."
49. See Finis Farr, *FDR* (New Rochelle: Arlington House, 1972); Hugh Gregory Gallagher, *FDR's Splendid Deception* (New York: Dodd and Mead & Co., 1988); Richard Thayer Goldberg, *The Making of Franklin D. Roosevelt: Triumph Over Disability* (Cambridge: Abt Books, 1981); William E. Leuchtenburg, *The FDR Years* (New York: Columbia University Press, 1997); Davis W. Houck, *FDR's Body Politics: The Rhetoric of Disability* (College Station, Tex.: Texas A&M University Press, 2003).
50. Rogers, *Dirt and Disease*, 166–9. See also Turnley Walker, *Roosevelt and the Fight Against Polio* (London: Rider & Co., 1954); John Duffy, "Franklin Roosevelt: Ambiguous Symbol for Disabled Americans," *Midwest Quarterly* 29 (1987): 113–35. For an interesting adolescent memoir, see the novelist Susan Richards Shreve's *Warm Springs: Traces of a Childhood at FDR's Polio Haven* (Boston: Houghton Mifflin Co., 2007).
51. On the history of the NFIP, see David L. Sills, *The Volunteers: Means and Ends in a National Organization* (Glencoe: Free Press, 1957); Richard Carter, *Gentle Legions* (Garden City, N.Y.: Doubleday, 1961).
52. Paul, *History of Poliomyelitis*, 301–23. For more on polio in the United States, see David M. Oshinsky, *Polio: An American Story* (New York: Oxford University Press, 2005).
53. See Ontario March of Dimes, *The Paul Martin Sr. Society: A Most Honourable Legacy*, video production, n.d., 11 minutes for Marching Mothers in Canada.
54. Rutty et al., "Conquering the Crippler," I-5; Rutty, "Do Something!" chap. 5.
55. Rutty, "Middle-Class Plague," 279.
56. Mrs George H. Gowland to Mitchell Hepburn, 27 October 1937, General Correspondence — Private 1937, Mitchell Hepburn Papers, Archives of Ontario.
57. John T. Saywell, *Just Call Me Mitch: The Life of Mitchell F. Hepburn* (Toronto: University of Toronto Press, 1991); Randall White, *Ontario 1610–1985* (Toronto: Dundurn Press, 1985), 229–34.
58. See Paul Martin, *A Very Public Life*, vol. 1, *Far from Home* (Ottawa: Deneau Publishers, 1983); vol. 2, *So Many Worlds* (Toronto: Deneau Publishers, 1985).

59. Murray Papers, RG 29, Vol. 34, File 311-P11-27.
60. See Emily Martin, *Flexible Bodies: Tracking Immunity in American Culture from the Days of Polio to the Age of AIDS* (Boston: Beacon Press, 1994).
61. "Iron Lung: A Powerful Symbol of a Greatly Feared Disease," *Life* (1975).
62. Lewis Thomas argues that halfway technologies are expensive and inferior to definitive technologies. Definitive technologies arise from basic research that reveals the inner working of the disease. In the case of polio, a definitive technology is the Salk vaccine. James Maxwell challenges this view and states that the iron lung was an important intermediate step in the evolution of modern-day respiratory equipment. See James H. Maxwell, "The Iron Lung: Halfway Technology or Necessary Step?" *Milbank Quarterly* 64, no. 1 (1986): 5–7.



CHAPTER 7

Replicating Form and Function: Artificial Body Parts

Replicating Form and Function: Artificial Body Parts

The Western biomedical model conceptualizes the human body as an array of parts that constitutes the whole. Furthermore, these parts are increasingly viewed as removable, alterable, and substitutable. Medical scientists have explored various ways of replacing diseased or damaged organs with human, animal, or artificial parts to restore or improve health in their patients. The challenges and successes of medical science in replicating form and function of specific body parts form an important story in the history of medicine, engineering, and technology. Questions arise such as, is function more important than form? To what extent has medical science's ability to replicate the function of specific body parts been life-saving?

Equally important is the social history of prosthetics, addressing questions such as, how does the replacement of body parts affect the identity of the individual? What role have patients played in the design and development of prosthetics? This line of inquiry expands into the history of disability, cultural understandings of the body, patient experiences, and material culture studies. To highlight some of these themes, this chapter focuses on two specific artificial parts — artificial limbs and the artificial kidney. After the First World War, the Canadian government pledged its commitment to providing artificial limbs to veterans, contributing to the development and improvement of prosthetic devices. In the case of the artificial kidney, the role of Toronto surgeon Gordon Murray will be emphasized.

Artificial Limbs

Historically, artificial limbs were worn mostly by individuals who survived a limb amputation.[1] Amputation surgery was often performed on soldiers injured during the course of battle as a life-saving measure. Other individuals needed an artificial limb or prosthesis as a result of industrial accidents, frostbite, animal bites, gangrene, or birth defects.[2] Yet not all patients survived amputation surgery, due to excessive bleeding or infection. In the nineteenth century, with the introduction of anaesthesia to control pain and later asepsis and antisepsis to limit infection, surgeons could operate more slowly and carefully, which improved patient survival rates. Surgeons devised skin flaps to cover exposed tissue and tried to leave a padded stump where possible so as to improve prosthetic fit and comfort for the patient. This was intended to reduce bone pain when bearing body weight on a leg prosthetic as well as infection from any rubbing of the stump surface. Little historical work exists that explores the influence of the amputation technique on prosthetic fit and design.[3]

Leg amputations outnumbered arm amputations, approximately four to one,[4] and were done for a variety of reasons, such as vascular deficiencies. The most common reason, however, was battle wounds. Veterans with amputations who returned home relied on crude wooden prostheses, and later mechanical arms and legs. Not surprisingly, improvement of amputation surgical technique along with the development of improved prostheses occurred after each major war.[5] For example, the "Anglesey Leg," designed by the London limb-maker John Potts, emerged as the first significant alternative to the peg leg when the Marquis of Anglesey, who had lost his leg in the Battle of Waterloo, commissioned this artificial leg in 1816.[6] The Anglesey Leg was a prosthesis consisting of a wooden shank and socket, a steel knee joint, and an articulated foot that was controlled by catgut tendons from the knee to the ankle. (The toe would lift when the knee was bent.) Thereafter the Anglesey Leg served as the basic model for most nineteenth-century wooden legs. Almost all artificial legs consisted of wood, often willow, covered in rawhide, with metal mechanisms and a foot with a rubber sole. They were attached to the body by fabric, elastic, or leather straps.[7] To imitate movement, the limb depended on cogs and gears, which proved to be problematic for wearers. As stated by Stephen Mihm, "This model . . . broke down, made considerable noise, and required frequent oiling; indeed amputees often carried an oil can with them to prevent the gears from binding."[8]

In 1894, Terence Sparham, a physician in Brockville, Ontario, received a patent for his prosthetic leg.[9] Compared with other Canadian designs of the period,[10] it was quite sophisticated, with moveable hinges at the knee, heel, and toe for increased movement. There was a spring in the toe, and the knee joint could be locked or loosened. A specially designed harness that went over the shoulder secured the leg to the body. According to patent records and supporting documents at Library and Archives Canada, "Sparham, with his partner, fellow Brockville entrepreneur and inventor, George Beacock, manufactured artificial limbs that reportedly enjoyed a good reputation in Canada's medical community. Beacock and his sons continued the company following Sparham's death in 1902."[11]

During the nineteenth century, designers struggled to replicate the form and function of human limbs. These artificial limbs moved neither easily nor silently for the wearer, often working against their natural gait or body movement. They were heavy, noisy, and often unreliable, thus prompting many individuals not to use the prosthetic. Wearers used words such as "jerking," "snapping," "rattling," and "uncontrollable gyrations" when describing their artificial limb.[12] In response, several changes were made in the mid-nineteenth century. To reduce the weight of the limb, manufacturers used light and flexible wood and they removed the cogs and gears. They focused on replicating the human form in both the interior and exterior of the artificial limb. As Stephen Mihm states, "It was not enough to craft artificial limbs that looked like real arms and legs; manufacturers spared no expense in producing artificial limbs that actually moved like real arms and legs."[14]

The Bly prosthesis and the Clement artificial leg, among other models, attempted to mimic the anatomical structure of the leg, for example by replacing mechanical springs with rubber springs to function as artificial muscles that contracted and expanded with the wearer. Limb designer Douglas Bly observed that "nature used not bolts or pins to bolt or fasten the foot to the leg, but . . . she nicely rounded the bones at the joint, and held them in place by means of ligaments, tendons, and muscles."[15] Thus when designing the ankle joint, Bly produced "a ball of polished ivory that fit into a socket of vulcanized rubber," which replicated the full range of motion of the human ankle.[16] According to Mihm, "Surgeons and doctors submitted testimonials that stressed the 'life-like motions of the joints' and the 'naturalness of form and movement' that this new generation of prostheses afforded."[17] The use of new materials (such as rubber springs) indeed contributed to the development of this new generation of artificial limbs; however, so did two other key factors.

The design and manufacturing of artificial limbs benefited, firstly, from the substantial number of surviving amputee soldiers after the Napoleonic Wars in Europe, the Civil War in the United States, and later the First World War. Secondly, the process benefited from the decision by federal governments to subsidize artificial limbs for veterans. In 1862, the U.S. federal government passed a law entitling each honourably discharged soldier or sailor to one artificial limb, and the lure of government contracts thus created stiff competition among manufacturers of replacement limbs to produce improved and cheaper prostheses. As described by the historian Katherine Ott, "By 1895 the U.S. government had granted 144 patents for legs and in 1917, as the United States entered World War I, there were 200 artificial limb manufacturers in the country."[18] After the First World War, the British government announced its commitment to provide artificial limbs to its veterans and established special limb units in hospitals.[19] As argued by Mary Guyatt, the ensuing demand by amputee ex-servicemen necessitated a major expansion and restructuring of the existing limb-making industry in Britain. Different manufacturers competed for government contracts to serve the military market.[20]

Figure 34. *The Canadian government provided all veterans with artificial limbs and also covered the cost of any necessary repair or replacement. This photo shows a veteran outfitted with an artificial lower arm and hook, circa 1918–25.*

(Library and Archives Canada, neg. PA-214103)

The Canadian government also pledged its commitment to provide artificial limbs to its veterans. Unlike Britain, however, Canada supported a government-owned-and-operated establishment to manufacture artificial limbs and other surgical appliances. There were no artificial limb factories in Canada with the capacity to provide enough devices. Furthermore, the Canadian government argued that one standard type of artificial limb was necessary to facilitate renewals and repairs of the device for veterans who would be living across the country. Lastly, "government proprietorship was further thought to be the best means of keeping in touch with and for adopting

all the latest improvements in designs from other countries."[21] There were few limb fitters and surgical instrument makers in Canada previous to the war. Many ex-servicemen, including amputees, were thus trained by the government as limb-makers and limb fitters, and placed accordingly.[22]

The first government shop supplying artificial limbs was opened in August 1916 in Toronto, in temporary factory space. It moved several times thereafter before finally securing a two-storey building on the grounds of the Dominion Orthopaedic Hospital at Christie Street, which handled all hospital cases and discharged men in the Toronto area.[23] Eventually branch depots were established throughout Canada — in Halifax, Saint John, Montreal, Ottawa, London, Winnipeg, Regina, Calgary, Edmonton, Vancouver, and Victoria. These depots were adequately staffed and equipped to provide renewals and repairs for veterans who had moved to these areas after receiving their first limb in Toronto, and consequently discharged from the service. The Christie Street hospital site, in Toronto, functioned as a fitting depot as well as the manufacturing centre for standard parts and sub-assemblies (such as stock sizes of shins, knee-blocks, feet), which were then shipped to the branch depots across Canada for completion. The fitter at the branch depot hand-shaped the socket or bucket in which the amputee's stump was placed, for individualized fit and comfort, before completing assembly of the artificial limb.

According to a 1920 report, the department, in charge of research, designs, and inspection of all standard-issue artificial limbs and appliances, contributed to several prosthetic improvements, including a differential arm, an adjustable drop foot splint, standardization of the knee joint, and more.[24] The report also stated that the cost of the government artificial limbs was substantially lower than commercial models: government artificial legs and arms cost $71.57 and $77.56 each, respectively, compared with commercial artificial legs and arms at $120 and $100 each.[25]

In the commercial arena, the emerging leaders in the limb-making market were A. A. Marks and J. E. Hanger and Company. A. A. Marks of New York was noted for significant improvements to the knee, ankle, and toe movements of the prosthesis. Founded in 1853, A. A. Marks advertised itself as the "largest manufactory of artificial limbs in the world" and published several editions of a *Manual of Artificial Limbs* in both the nineteenth and early twentieth centuries. Almost 400 pages in length, the manual was both a catalogue and source of information, with a strong promotional tone. The company's specialty was artificial limbs with rubber feet and hands, which it invented and patented. In the 1910s, it advertised the "spring mattress rubber foot" and the "rubber hand with ductile fingers" as the most recent improvements.

Figure 35. *Men finishing artificial limbs, circa 1918–25. Many ex-servicemen, including amputees, were trained as limb-makers and limb fitters after the First World War and employed in limb-manufacturing establishments owned and operated by the Canadian government.*
(Library and Archives Canada, neg. PA-214105)

A. A. Marks provided prostheses for foot amputations, ankle-joint amputations, below-knee amputations, knee-bearing stumps, thigh or femoral stumps, hip-joint amputations, double leg amputations, hand amputations, wrist-joint amputations, forearm amputations, elbow-joint amputations, above-elbow amputations, shoulder-joint amputations, and double arm amputations. The company fitted all amputees by custom measurement, arguing that mass production could not accomplish the necessary fit. Customers were advised to patronize a nearby U.S. location to be measured or to request that their physician take the required measurements, which Canadian customers did.

Interestingly, the A. A. Marks manual discussed cosmetic as well as practical reasons to invest in an artificial limb. For example, the manual stated that "a person will make a better appearance with an artificial arm properly dressed than with

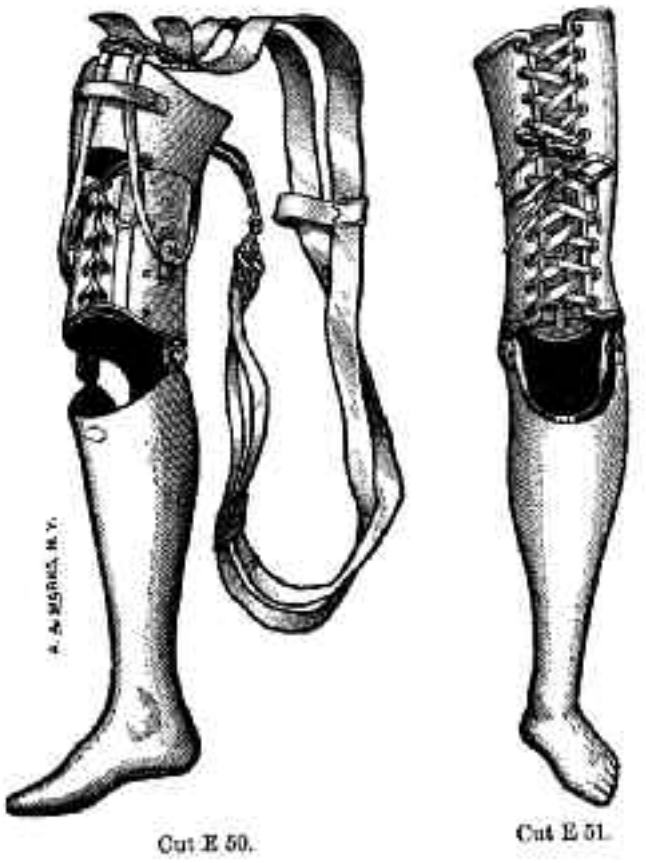


Figure 36. *An artificial leg for a below-knee amputation manufactured by A. A. Marks of New York, circa 1917. The company was noted for significant improvements to the knee, ankle, and toe movements of its prostheses.*
(George Edwin Marks, *Manual of Artificial Limbs* [New York, 1917], 68)

an empty sleeve."[26] The company may have had a persuasive argument on this point for some consumers. Culturally, an empty sleeve or trouser leg may have been seen as a badge of honour for a veteran,[27] but for others, including victims of industrial accidents or birth defects, this may not have been the case.[28] For example, many female amputees sought to hide or disguise their artificial limb so as to "pass" for able-bodied.[29] The prosthesis therefore served to alter the disabled body into a near "normal" body in a Western culture quick to label differences as disabilities.[30] Male amputees were less interested in disguising the prosthesis than in demonstrating the utility of their artificial limb, and manual photographs showed them at work or pursuing leisure activities made possible due to their prosthesis. Recognizing the broad audience for artificial limbs, the A. A. Marks manual included images and advice for men as well as women and children in need of prostheses.[31]

In addition to providing illustrations of their prostheses and device instructions for the potential recipient, the manual also published customer testimonials. Apparently many Canadians were satisfied with their A. A. Marks products, including Robert E. Blackshaw of Montreal with a below-knee prosthetic who wrote: "Am pleased to say the artificial limb you made for me in 1902 is giving continued satisfaction. People whom I meet, who are not aware that I am wearing an artificial limb, find it very hard to believe it. As I see others walking around, wearing limbs not manufactured by you, I feel glad that I was led to you for mine."[32] Dr Wilfred C. Bliss of Saskatchewan, who sent measurements on behalf of his patients to A. A. Marks, wrote: "Regarding artificial legs purchased through me for my patients, would state that they have given satisfaction. They not only wear well but give such comfort with so little noticeable limp, that wearers tell me they often deceive their friends, these not knowing an artificial limb was being worn."[33] Gerald A. Garland, a farmer in New Brunswick, reported: "I can truly say that the artificial hand I bought from you has been of great service to me. I can do lots with it that I cannot do without it. I do all my own hay pitching and I can use the shovel good and I do all my own hoeing in the garden. I am well satisfied in every way and I would advise any young man that has lost his hand to buy one like mine."[34] Though these testimonials are certainly biased and selected to promote the sale of artificial limbs, they suggest that some Canadians resumed near-normal activities and workloads with the assistance of prostheses.

Experience gained from the many thousands of amputations during the First and Second World Wars led to marked advances in surgical technique and in the design and mechanical efficiency of prostheses. Artificial legs and arms became less heavy with the use of lighter metals and woods, and attention was given to ventilation to avoid an unhealthy condition for the stump. A constant was the necessary skill of the limb fitters, who were often amputees themselves, working closely with medical men and often in specially established prosthesis workshops in veterans' hospitals. One such specialty hospital in England was Queen Mary's Hospital for the Limbless in Roehampton, where many hundreds of limbless civilians and ex-servicemen were fitted with artificial limbs under the direct supervision of Limb-Fitting Surgeons.[35] In the United States, an artificial limb lab was established at Walter Reed Hospital in 1918.[36] In Canada, most amputee ex-servicemen were fitted at the Christie Street hospital in Toronto.

After the First World War, the "Hanger Leg" was supplied by the British and Canadian governments to their disabled ex-servicemen. The Hanger metal leg weighed less than half of the standard "Anglesey Leg," and was just as strong.[37] Early light-metal legs were a mass of riveted parts; the Hanger company was the first to form the shin of the leg in a one-piece seam-

less pressing drawn from a flat sheet. The result was a much lighter and stronger leg. The Hanger leg also had a "precision-made ball-bearing" knee joint, "roller-bearing" ankle joint, "a knee joint locking device," and "improved knee spring," among its patented improvements.[38] Pelvic bands or leather thigh corsets kept the artificial leg in place.

In 1926, the Canadian government entered into a contract with the J. E. Hanger Company, whereby the company agreed to supply the component parts required for the manufacture of metal legs as well as supervise the installation of the necessary machinery in the Toronto limb-manufacturing centre.[39] As soon as the new metal limb shop was operational, limb fitters from the branch depots were brought to Toronto for instruction in the measuring and fitting of these special limbs. Wooden legs were less than one-third the price of metal legs, which explained the initial resistance by governments; however, the superiority of metal legs could not be ignored, for many ex-servicemen who could afford metal legs assumed the cost themselves.[40] The Hanger company, like its competitors, also published customer testimonials. W. Niven, from Hesketh, Alberta, wrote: "I left Kinross, Scotland for Alberta, Canada to help my brother with his farm about twelve months ago and now, with the help of our artificial leg, I can do anything on the farm. I drove a team of horses and a binder all last harvest with the greatest ease, also a team of six in a disc, of which I have much pleasure in enclosing a snap of me at work."[41]

Figure 37. *This light-metal leg, circa 1936, was used in cases of amputation above the knee. The Hanger company was the first to form the shin of the leg in a one-piece seamless pressing drawn from a flat sheet, resulting in a much lighter and stronger leg.*

(*"Solvitur Ambulando": A Symposium on Prosthetic Achievement* [London: J. E. Hanger & Co., 1936], 11)

The United Limb and Brace Company, an American company, had a branch office in Toronto and also marketed its product to both Canadian and American customers. Its slogan "United limbs make life's walk easy" was intended to bring attention to its special "Slip-Socket" component. Chafing, binding, or irritation often plagued amputees, making walking or even just wearing the prosthetic uncomfortable if not painful. Artificial limbs with sockets constructed of leather or rawhide tended to lose their shape from perspiration, stump pressure, or climatic conditions. The United "Slip-Socket," also made of leather, incorporated an aluminum insert with added cushion and springs to retain shape but still fit snugly against the stump. This aluminum socket, the company declared, "cannot expand or contract . . . [which] absolutely prevents the socket from rattling after long and continuous use," as compared with competitors' wooden guides that were glued in the leather socket.[42] The company advertised a 5 percent return on the purchase price of any prosthetic in U.S. Liberty Bonds or Canadian Victory Bonds and anticipated its "conscription" into duty to provide artificial limbs to returning soldiers to aid their "re-establishment into civil life."[43]

During the interwar period, manufacturers continued to explore new materials and new designs to improve the function of artificial limbs. For example, early artificial arms and hands had limited movement. According to Katherine Ott: "Hands were designed for a single activity. The client had a hand made to suit his or her most frequent activity, such as holding cards, grasping a pen, gripping a knife or pistol, or remaining rigid. A hand had no variable tension or pinch — only hold and release functions, activated by a button."[44] Not until after the Second World War did myoelectric activation make increased movement possible. (Myoelectric activation of prosthetics works by utilizing the electrical signals within the body that stimulate muscles to move. The body's low-voltage electrical signals are amplified and redirected to operate the battery-driven, moving elements of prosthetic devices.) By this time, the "telltale joint snap or clapping sound when a foot hit the group or clip as the shoulder cable released" had been significantly lessened by engineers and designers working on artificial limbs.[45]

According to Mary Guyatt, the two technologies of wood and metal coexisted side by side up to and beyond the Second World War (and she notes that some wooden and metal artificial limbs are still manufactured today).[46] Guyatt also argues that despite attempts at standardization, the manufacturing of artificial limbs — whether wood or metal — was still a craft-based skill in which individual measurements, fit, and comfort were paramount. This changed with the introduction of plastics and associated methods of production in the 1950s. Volunteer and government organizations, as well as industry, participated in the artificial limb story. In Canada, the War Amps, founded in 1920, aimed to provide practical assistance to disabled veterans and later civilians with employment, counselling, and artificial limb information. This group introduced innovative programs and ideas to help adults and children cope with their amputations.[47] After the Second World War, the National Academy of Sciences in the United States established the Artificial Limb Program to promote and co-ordinate scientific research on the improvement of prosthetic devices. Researchers studied the movement of normal human limbs in order to emulate function more effectively. New plastics and other materials, such as carbon fibre, have allowed artificial limbs to become stronger and lighter, limiting the amount of extra energy necessary to operate the limb. Further improvement of prosthetics occurred due to computer-aided designs and collaboration between doctors and engineers.

The Artificial Kidney and Gordon Murray

An artificial kidney mechanically replicates the functions of the human kidney, providing either short- or long-term support that can save an individual's life.[48] The primary function of a kidney is the elimination of liquid waste. A number of conditions — such as acute toxaemia, acute nephritis, and injury or obstruction to the ureters and kidney — cause this organ (or pair of organs) to shut down.[49] When the kidneys stop functioning, uraemia results: deadly poisons accumulate in the body; and when the body becomes unable to cope with the excess poisonous waste in the

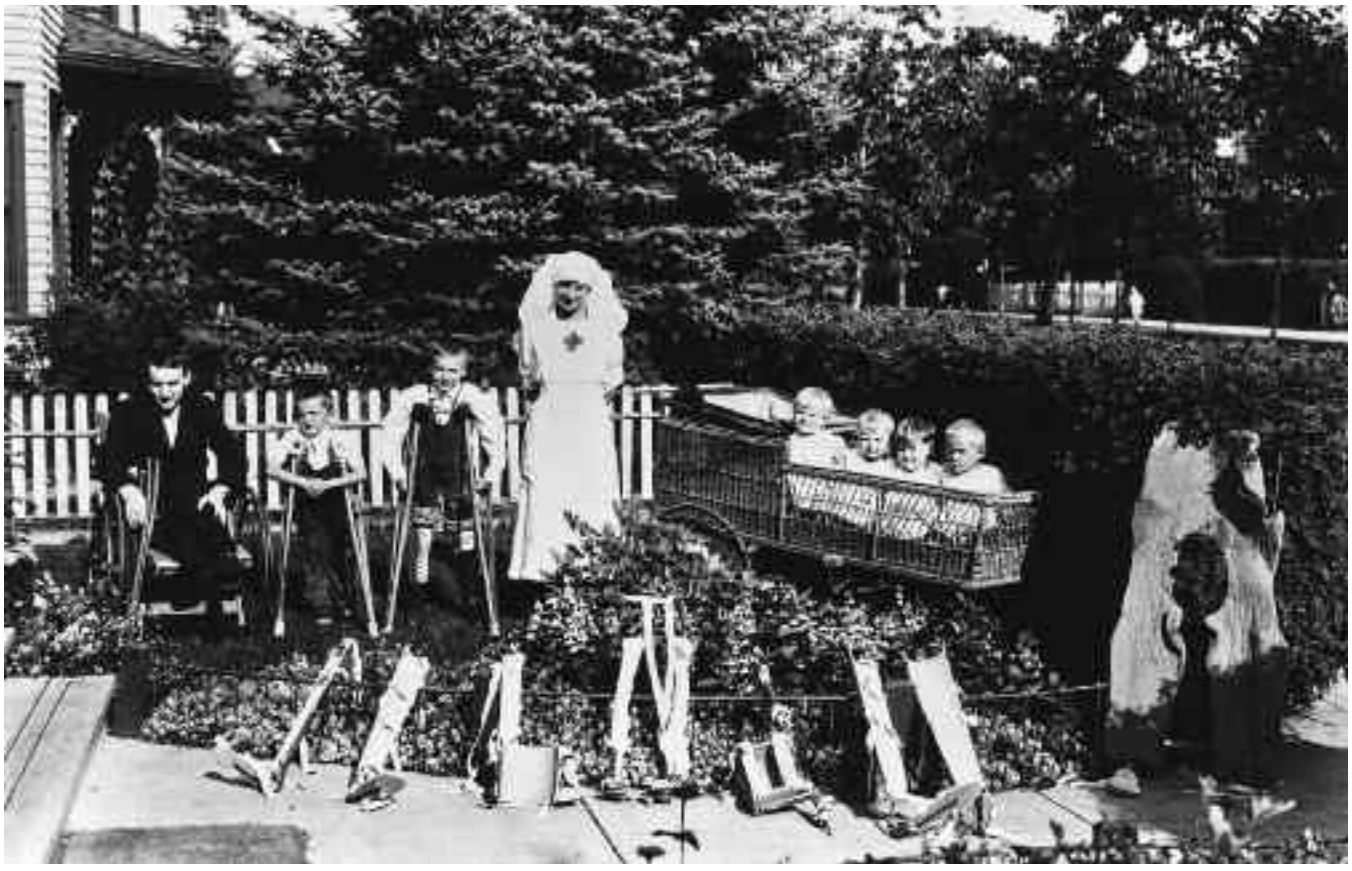


Figure 38. *Nurses and patients outside the Junior Red Cross Children's Hospital in Calgary, 1922. Originally, the hospital was situated in a three-storey home, with 35 beds and volunteer physicians. With increased demands for children's health care, the hospital moved to a larger, renovated apartment house and was renamed the Red Cross Crippled Children's Hospital in 1929.*

(Glenbow Archives, NA02903-12)

blood, the patient may experience nausea, vomiting, lethargy, and drowsiness, before lapsing into a coma. Eventually, the patient dies. An artificial kidney provides the mechanism by which the accumulated poisonous wastes can be excreted. It might also save the patient's life. If not severely damaged or diseased, the patient's kidneys might recover completely once the excessive buildup of waste products is removed from the bloodstream.

The artificial kidney is a dialyser, a machine external to the body that "cleans the blood." It removes waste materials, or poisons, by filtering the blood through a semipermeable membrane. By means of extracorporeal circulation, blood is taken from the patient and pumped through this membrane, or tube, into a dialysate bath. Blood cells and proteins remain in the tube, while water, salts, sugar, amino acids, and waste products pass into the dialysate, or dialysing solution, a mixture of water and salts. The blood, cleansed of waste products, is returned to the body. The artificial kidney therefore contains three basic elements: a dialysing membrane or tube, a dialysing solution or dialysate, and a mechanism for circulating blood through the machine. Successful vividiffusion experiments on dogs had been carried out as early as 1913 by J. J. Abel, L. G. Rowntree, and B. B. Turner at Johns Hopkins University.[50] Early artificial kidney prototypes emerged in Holland and Sweden, then later in England and North America, where they were used on patients.[51]

Few people even among nephrologists are aware that the Canadian surgeon Gordon Murray (1894–1976) built the first North American artificial kidney. Perhaps this is because the Dutch physician Willem J. Kolff is correctly recognized as the "inventor" of the artificial kidney, or because Murray's fame came from his work in cardiovascular surgery. Murray became interested in renal therapy during the 1940s after seeing several patients die of uraemia.[52] Frustrated by the medical profession's ignorance of this disease, he began investigating the kidney with the prospect of mechanically replicating its functions. In the end, Murray built two different artificial kidney machines. His first successful artificial kidney was built in 1945–46, with the assistance of Edmund Delorme and Newell Thomas. In 1952–53, a second-generation, improved model was designed and constructed by Murray and Dr Walter Roschlau. Unfortunately, these artificial kidneys remained crude prototypes and were never refined or commercially produced for wider distribution. Reasons for this failure relate to the medical culture in which Murray's machines were constructed and utilized. At the time, experimentation was encouraged in the laboratory, not on hospital wards, and the designation of the artificial kidney as experimental persisted despite Murray's efforts to demonstrate otherwise.

Murray's First Artificial Kidney Machine (1945–46)

As no one had yet designed and used an artificial kidney when he began his experiments, Murray encountered several technical difficulties in the building of his first artificial kidney. These included discovering a suitable dialysing membrane, finding the proper dialysing solution or dialysate, and selecting a viable mechanism for circulating blood through the machine. The dialysing membrane that led the blood through the dialysate had to be a semipermeable membrane to allow the molecules of harmful wastes to pass into the dialysate. After experimenting with various natural and synthetic products and following the work of William Thalhimer in New York,[53] Murray found that the best semipermeable membrane was a type of cellophane used for sausage casing in the form of long tubes. He experimented with the size and length of tubing before settling for the satisfactory size of 1/4 inch (6.5 mm) in diameter, varying in length from 35 to 150 feet (10 to 50 m). The tubing was coiled vertically around a wire-mesh cylinder and contained in a large bath jar or drum filled with the dialysate.

Next, Murray sought a dialysate consistent with the normal substances of the blood. After a number of false starts, he settled on Ringer's solution, formulated to balance the chlorides, calcium, magnesium, potassium, sodium, phosphate, bicarbonate, and sugar in the blood. To circulate the blood through the machine, Murray decided to work exclusively within the venous system, taking blood from and returning it to a vein, using a novel pump system that reduced blood damage. (This was in contrast to arterio-venous circuiting chosen by other pioneering researchers, notably Kolff and Nils Alwall.) A rubber tambour was inflated and deflated by the action of the piston-syringe, acting as the pump, attached to an electric motor. Intake and outlet valves controlled the blood flow. Tinkering with the relatively simple materials at hand, Murray completed the building of his prototype machine.[54]

To test his artificial kidney, Murray first ran trials with uraemic animals, treating them for hours, even overnight, with relative success.[55] The real test, however, came with Murray's first clinical case, in December 1946. A 26-year-old female patient lay in a uraemic coma at the Toronto General Hospital as a result of an abortion attempt. Her doctors declared her case hopeless, and they called Murray. They were not convinced that the artificial kidney would actually work, but were at a loss as to what else to do for the patient. They agreed to the experimental therapy because the alternative seemed to be certain death.[56] Murray quickly arrived on the ward with his odd-looking machine. It was massive and cumbersome; three men were required

to carry it to the bedside. The patient was connected to the artificial kidney through long plastic catheters inserted into the veins. Heparin solution (the other vital component for successful dialysis that Murray had himself helped to develop, as discussed in chapter 4) was then injected into the patient's bloodstream and into the machine. When the machine was switched on and its pump started moving, dark red venous blood was carried into the cellophane tubing and slowly flowed through the narrow coils submerged in the dialysate contained in a 15-quart (14 litre) glass jar perched on the bedside table. The blood then passed through an air trap that removed any bubbles and returned to the patient's circulatory system. A thermostat control had been built into the machine to maintain the patient's blood temperature outside the body.[57]

The patient's condition appeared to improve, but after one hour, she developed a severe chill. Murray discontinued the treatment immediately.[58] Over the following days, the patient received several treatments. She was comatose at the beginning of each treatment, but was revived and alert by the end of the session. It was a trial-and-error approach to regulating the treatments. It was the first time that the Toronto artificial kidney had been used, and Murray did not know how long the patient's kidneys needed to rest before resuming their function. Eventually, there was an enormous output of urine. The patient's kidneys had begun to function, and residual poisons and excess liquids were soon washed out of her body. She made a steady recovery and was released from hospital thirty-three days after being admitted.[59]

It was a celebrated case. Newspapers reported it as yet another life-saving treatment by the doctor already famous for saving "blue babies" from congenital heart disease. "Artificial Kidney Saves Human Life," "Dr. Murray's Machine Restores 'Dead' Girl," and "Sausage Casing Used as Kidney Saves Lives" were some of the headlines.[60] Murray described his mechanical invention and his success at treating acute kidney failure at medical meetings in Chicago and in London, England.[61] Doctors, hospitals, and manufacturing companies wrote to Murray, asking him for specifications of his artificial kidney.[62] According to Murray, anyone could build an artificial kidney. "It is a very simple arrangement."[63] The most expensive item was the motor and pump component of the machine. He was shocked to learn that a Buffalo maker was selling a model for $600. By 1951, the Allis–Chalmers Manufacturing Company in Wisconsin had sold six artificial kidneys at $3,600 each.[64]

Murray's machine had been the first successful North American model, but it was only one of several prototypes in the world.[65] Willem J. Kolff invented the

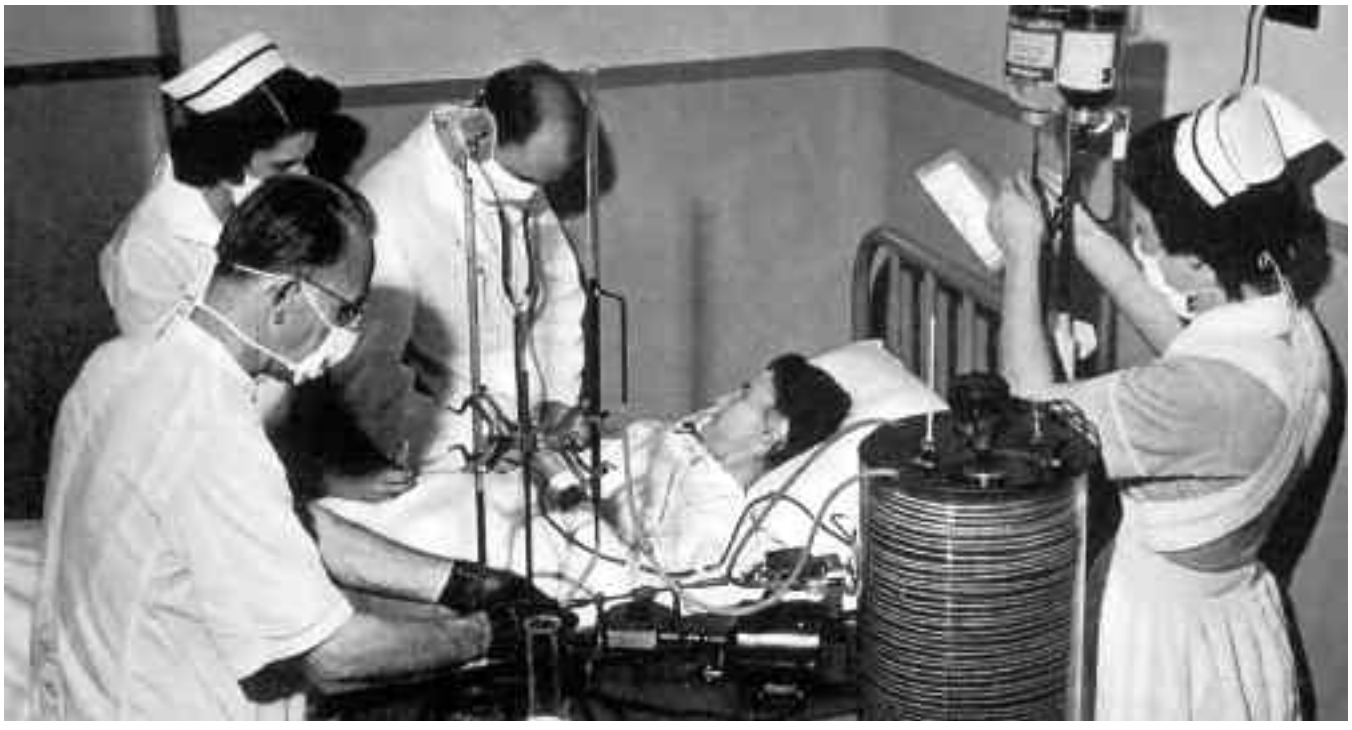


Figure 39. *In this staged photograph from 1945–46, Dr Gordon Murray (front left) demonstrates his vertical coil artificial kidney machine. Note the numerous individuals required to administer treatment with the artificial kidney as well as the significant size of the machine at the bedside.*

(Reprinted with permission from the *Saturday Evening Post*, circa 1950)

artificial kidney in 1943 in occupied Holland.[66] Murray stated that he had not received any information about Kolff's work until after the war, maintaining that "our efforts have been going on apparently simultaneously and independently."[67] Notable design differences in the two machines suggest that Murray was indeed unaware of Kolff's unit.[68] Numerous doctors in various American centres and elsewhere also expressed interest in the artificial kidney — both the Kolff and Murray models — and they asked for more information, even design sketches, so they too could build their own machines.

These artificial kidneys, however, were still experimental and offered only a short-term, intermittent treatment to patients suffering from acute renal failure. There remained problems of sustaining patients on the machine for lengthy periods of time and of exhausting usable arteries and veins for treatment. Some patients who received treatment by the artificial kidney regained adequate renal function, due to their own kidneys being allowed a "rest" and their body being "detoxified" by the machine, but for many patients, this did not happen.[69] Consequently, opponents of this therapy, notably British doctors, viewed the artificial kidney as unsafe, and they cited occurrences of patient hemorrhaging, dehydration, or water overload.[70]

North Americans were more enthusiastic about the artificial kidney. The media reported the "life-saving" capability of these machines and showcased the various homemade machines built by local doctors. Montreal and Vancouver papers incorrectly reported that they had the first and second artificial kidneys in Canada, respectively.[71] Most American and Canadian prototypes were based on Kolff-like designs, perhaps modified by their clinician-inventors, each claiming improvements or advantages.[72] Kolff's model also became the standard on which manufacturers based their commercial models, for his work and artificial kidney design were more well-known professionally and commercially than Murray's. Few people outside of Toronto seemed to even be aware of Murray's machine.[73]

Murray had built the machine and proved its efficacy in treating acute renal failure, but it was used comparatively less at the Toronto General Hospital than elsewhere. By 1949, Murray had treated only eleven patients with the artificial kidney, of whom five survived.[74] This number increased to sixteen by 1952, many of them public ward cases treated without charge, according to his secretary's records.[75] But as Dr William Clarke observed: "One of the major problems faced by Murray was a shortage of trained, knowledgeable personnel, which meant that he often had to be personally involved throughout the dialysis. The procedure usually had to be carried out overnight, with a full day's work scheduled for the next day."[76] Dr G. G. Caudwell, a resident of Murray's, remembers how Murray's interns "dreaded the call" for attending a patient on the artificial kidney, because it required "24 hours of continuous monitoring."[77] Murray's machine was moved to the basement of the Toronto General Hospital and seldom used after 1949.[78] Although it was a secondary line of investigation to his cardiac surgery, Murray did not abandon his artificial kidney work entirely, despite his frustration at the hospital's lack of support for and lack of interest in renal therapy.

Murray's Second Artificial Kidney Machine (1952–53)

By the early 1950s, Murray was director of a privately funded laboratory — the W. P. Caven Memorial Research Foundation — with full-time research staff. At the Caven Foundation, Murray decided to build a second, improved machine in 1952–53. By this time, a greater number of commercial and homemade artificial kidney machines were being circulated and used in North American and European hospitals. During the 1950s, more than twenty new designs of the artificial kidney emerged, predominantly modified versions of the Alwall kidney and the Kolff kidney, which featured a rotating-drum device. Murray, however, found the Kolff kidney "large and cumbersome . . . [and] quite expensive." He concluded that he might be able to design "a small working model which will be very compact and not very expensive."[79] In addition to being large and costly, artificial kidney machines still produced mixed results in treating renal therapy. With Walter Roschlau's assistance, Murray attempted to offer a more compact and efficient machine to the medical marketplace.[80]

The Murray–Roschlau "second generation" artificial kidney of 1952–53 was an improved model from the original machine with substantial differences. The significant feature of this machine was its parallel plate dialyser instead of the original vertical coil dialyser, making it much more compact. Roschlau (who appeared to have been unaware of similar designs by Leonard Skeggs and Jack R. Leonards at Case Western Reserve University, Cleveland, and by Arthur McNeil in Buffalo)[81] had designed a plate-type dialyser with an enlarged surface area and reduced blood-volume requirements. He experimented with flow patterns, volume requirements, dialysing membrane surfaces, and the production of multiples of blood- and dialysate-chambers. The first Murray artificial kidney machine was cannibalized for its electric motor, mounting boards, glassware, and so on.

One deliberate design change was the placement of the fluid storage container under a bedside table, an attempt to show "less machine" at the bedside and thus have it appear less "frightening" to the patient and

observers. The machine's operation was simplified, it was easier to handle, and its efficiency improved. In 1954, twenty-seven experiments involving ten dogs were conducted to test the performance and reliability of the new machine. In late 1955, the second-generation artificial kidney was used in two clinical cases. The experimental therapy once again brought successful results. No flaws in the design or function of the machine were noted. However, these clinical cases were never reported.[82]

Before Murray and Roschlau announced the outcome of their work, one of the engineers, Erwin Halstrup, returned to Germany with the designs of the improved artificial kidney. (Halstrup, who had recently arrived from Germany, had helped them develop a new pump and change the prototype from Plexiglas to metal.) Shortly after Halstrup left Canada, Murray and Roschlau received letters from two German medical schools asking them for their experience with the Halstrup–Baumann artificial kidney. Recognizing the design, Roschlau was devastated and Murray outraged! With the help of Baumann, a Germany company, Halstrup was marketing a parallel-plate dialyser machine strikingly similar to the Murray–Roschlau kidney to medical clinics and hospitals in Germany.[83] Roschlau had not sought patent protection, and Halstrup had done nothing illegal. At that point, Murray probably felt that he had lost control over his own machine. Furthermore, he was pursuing research in cancer, a more promising area that demanded his full attention. He dropped his work on the artificial kidney.[84]

Murray lost all interest in the artificial kidney when he lost control over the designs of his machine. Moreover, his machine benefited very few patients. For Murray, developing the kidney machine prototypes had been a bitter experience, frustrated by insufficient research funds and by the reluctance, even disinterest, of his Toronto colleagues in new procedures and technology. What he did not understand was that many doctors were concerned with protecting their patients from ill-conceived experiments, and during the 1940s and early 1950s, most Toronto medical men viewed the artificial kidney as experimental. Like many of the previous generation of doctors, they were wary of machines and took a conservative stance towards the new technology being brought into the hospital, unlike many of their American counterparts. Unfortunately for Murray, for patients, and even for the Toronto General Hospital, his artificial kidney did not bring about a commitment or leading role by Toronto medical men to establish a dialysis treatment program. Not until 1958 was a dialysis service organized, by members of the Department of Urology, Medicine and the Division of Laboratories at the Toronto General Hospital, and the first patient was treated in January 1959.[85] By this time, Murray had left the hospital and had turned his attention to new research projects in unrelated medical fields.

Conclusion

Artificial limbs and the artificial kidney are examples of medical technology's attempts to replicate form and function of certain body parts. In these particular cases, devices and machines have contributed to improving or maintaining life. They also illustrate a type of body-machine interface. Artificial limbs serve as tools to improve mobility and function, enabling many recipients to return to "normal" activities and to regain a "normal" body image. What is considered to be "normal," "able-bodied," and "attractive" is culturally specific, and certainly differs from individual to individual. But we do know that for many individuals with prostheses, the artificial limb becomes a part of them; the technology becomes embodied.

Medicine values cures above all, and although neither artificial limbs nor the artificial kidney provide a cure, these devices are successful substitutes to control and manage disability and disease. If in Western biomedical medicine the body is an entity of parts, then study of form and function of the part and how it fits into the whole can yield information on how best to substitute parts. Form entails a study of materials, mechanics, and hardware, while function necessitates attention to design and employment. Some engineers have begun experimental development of parts that expand beyond nature's form and function, such as hand prostheses with sensors that communicate with computers and bypass the keyboard hardware.[86] The evolution of prostheses highlights shifting outlooks about health, body appearances, and body functions for amputees, the medical community, and society in general. The relationship between the body and technology is framed by the limits of technology, the complexity of the body, and the social and cultural context in which that relationship is created.

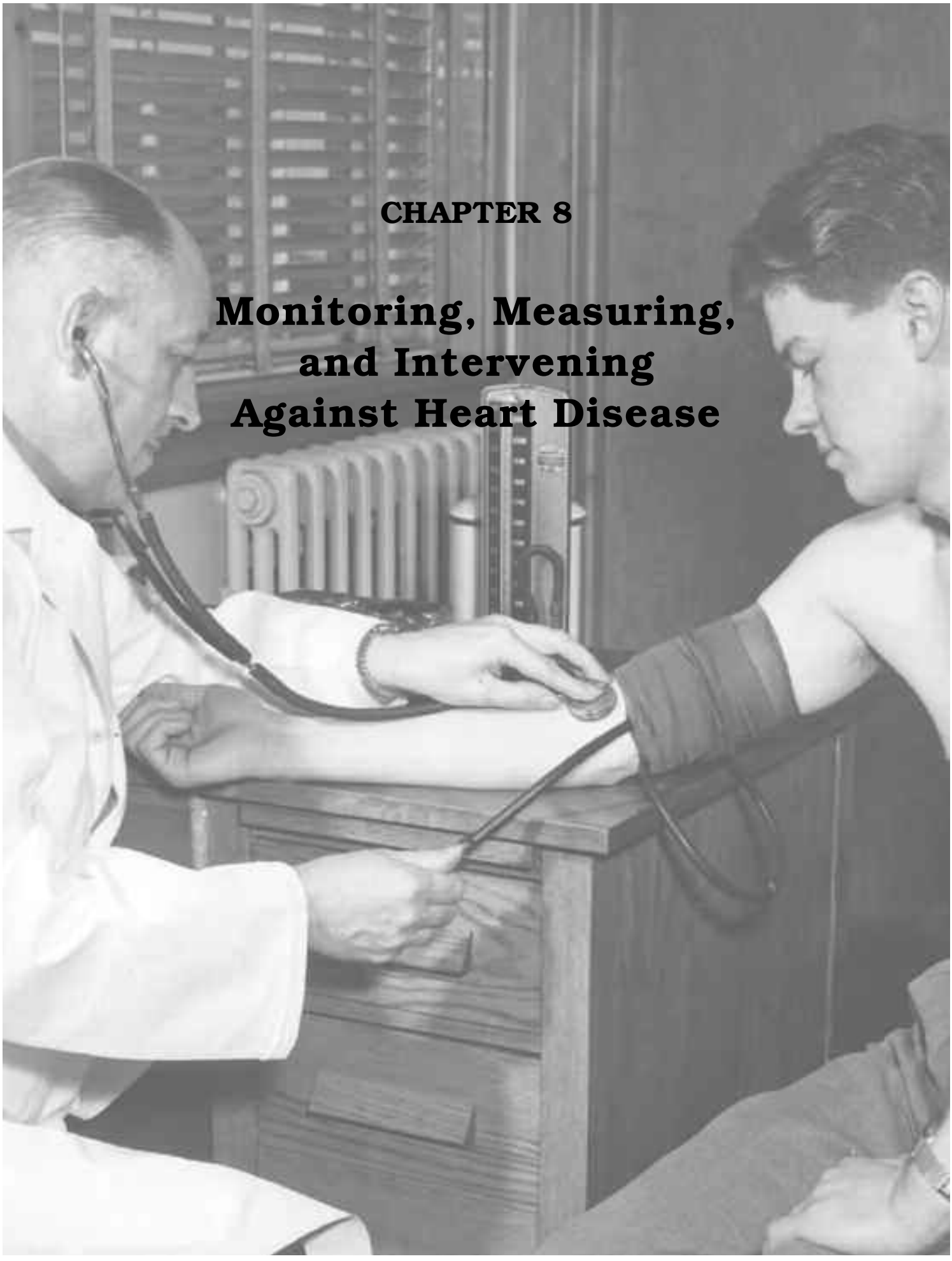
Notes

1. For an overview history of amputation before the twentieth century, see Owen H. Wangensteen and Sarah D. Wangensteen, *The Rise of Surgery: From Empiric Craft to Scientific Discipline* (Minneapolis: University of Minnesota Press, 1978), chap. 2, "Wound Management in Amputation," 16–52.
2. See John Kirkup, *A History of Limb Amputation* (New York: Springer Publishing Company, 2006); A. B. Wilson, "History of Amputation Surgery and Prosthetics," in *Atlas of Limb Prosthetics: Surgical, Prosthetic, and Rehabilitation Principles*, ed. J. H. Bowker and J. W. Michael (St. Louis: Mosby, 1992), 3–13.

3. Katherine Ott, "The Sum of Its Parts: An Introduction to Modern Histories of Prosthetics," in *Artificial Parts, Practical Lives: Modern Histories of Prosthetics*, ed. by Katherine Ott, David Serlin, and Stephen Mihm (New York: New York University Press, 2002), 13. For background on amputation during the Civil War, see Laurann Figg and Jane Farrell-Beck, "Amputation in the Civil War: Physical and Social Dimensions," *Journal of the History of Medicine and Allied Sciences* 48 (1993): 454–75; Ansley Herring Wegner, *Phantom Pain: North Carolina's Artificial-Limbs Program for Confederate Veterans* (Raleigh, N.C.: North Carolina Office of Archives and History, 2004).
4. Ott, "Sum of Its Parts," 14.
5. One of the many themes of Mary Guyatt's work on the limb-making industry in Britain is the idea of conflict as a force of change. See "Better Legs: Artificial Limbs for British Veterans of the First World War," *Journal of Design History* 14, no. 4 (2001): 307–25.
6. John Potts had patented his artificial leg in 1805, however, as stated by Mary Guyatt, "It seems to have taken the patronage of the Marquis of Anglesey for the device to become well known." "Better Legs," 308n7.
7. Ibid., 309.
8. Stephen Mihm, " 'A Limb Which Shall Be Presentable in Polite Society': Prosthetic Technologies in the Nineteenth Century," in *Artificial Parts, Practical Lives*, ed. Ott, Serlin, and Mihm, 284.
9. Filed in 1894, patent #45172 was issued to the prosthetic leg application of James Hall and Terence Sparham. Sparham held several patents for artificial limbs, including #23972 (artificial leg), issued in 1886; #22698 (artificial arm), issued in 1885; #45220 (artificial arm and hand), issued in 1894; and #19800 (artificial hand, artificial leg), issued in 1884. See the Library and Archives Canada patents database at www.collectionscanada.ca/archivianet/patents/001038-100.01-e.php (accessed December 12, 2007).
10. An artificial leg patented ten years earlier in Douglas, New Brunswick, #19681, is basic by comparison. www.collectionscanada.gc.ca/innovations/023020-2630-e.html (accessed November 29, 2007).
11. Ibid. See also John Joseph Heagarty, *Four Centuries of Medical History in Canada*, vol. 1 (Toronto: Macmillan, 1928).
12. Mihm, "Limb Which Shall Be Presentable," 284.
13. Ott, "Sum of Its Parts," 24.
14. Mihm, "Limb Which Shall Be Presentable," 284.
15. Ibid.
16. Ibid., 285.
17. Ibid., 286.
18. Ott, "Sum of Its Parts," 26.
19. See Jeffrey S. Reznick, *Healing the Nation: Soldiers and the Culture of Caregiving in Britain during the Great War* (Manchester: Manchester University Press, 2005); Nicholas J. Saunders, ed., *Matters of Conflict: Material Culture, Memory and the First World War* (New York: Routledge, 2004).
20. Manufacturers who secured government contracts were also given workshop space in designated hospitals. Successful manufacturers included several long-established members of the British limb-making industry — among them Chas. A. Blatchford and Sons, W. R. Grossmith, Masters and Son, and Charles Salmon and Sons — as well as several American companies — Carnes Artificial Limb Company, J. E. Hanger, and J. F. Rowley. Guyatt, "Better Legs," 311.
21. Canada, Parliament, *Sessional Papers*, Vol. 5, Fourth Session of the 13th Parliament of the Dominion of Canada, Session 1920, Department of Soldiers' Civil Re-establishment, *Report on Orthopaedic and Surgical Appliances*, 26.
22. In the report of 1920, the number employed in limb-making and limb-fitting was 348 — the majority being ex-servicemen and 48 of which were amputees. Canada, *Sessional Papers* 1920, 27.
23. The first shop was opened at No. 47 Buchanan Street, Toronto, with a practical limb-maker in charge of 6 men and 1 boy. This staff was later increased to 13. In February 1917, the shop was moved to larger premises at 426 Yonge Street, but soon outgrew this space. As a result, the sixth (or top) floor of the Keens building at 185 Spadina Avenue was acquired, and soon after the fifth floor was taken over. Late in 1917, the shop moved to the grounds of the Davisville Hospital, then finally to the Christie Street location. The factory at the Keens building continued to produce parts for branch depots. Canada, *Sessional Papers* 1920, 26–7.
24. Ibid., 28.
25. Ibid.
26. George Edwin Marks, *Manual of Artificial Limbs: An Exhaustive Exposition of Prothesis* (New York, 1918), 183.
27. Ott, "Sum of Its Parts," 27.
28. See Erin O'Connor, " 'Fractions of Men': Engendering Amputation in Victorian Culture," *Comparative Studies in Society and History* 39, no. 4 (1997): 742–77.
29. Marquard Smith, "The Vulnerable Articulate: James Gillingham, Aimee Mullins, and Matthew Barney," in *The Prosthetic Impulse: From a Posthuman Present to a Biocultural Future*, ed. Marquard Smith and Joanne Morra (Cambridge: MIT Press, 2006), 54.
30. See Lennard Davis, "Constructing Normalcy," in *The Disability Studies Reader*, 2nd ed., ed. Lennard Davis (New York: Routledge Press, 2006); Roger Cooter, "The Disabled Body," in *Medicine in the 20th Century*, ed. Roger Cooter and John Pickstone (Amsterdam: Harwood Academic Publishers, 2000, 367–83).
31. Marks, *Manual*.
32. Ibid., 268.
33. Ibid.
34. Ibid., 300.
35. *"Solvitur Ambulando": A Symposium on Prosthetic Achievement* (London: J. E. Hanger & Co., 1936), 4.
36. Ott, "Sum of Its Parts," 15.
37. In the 1920s, aluminum-alloy duralumin — an alloy of aluminum, copper, and magnesium that possesses the matchless properties of exceptional strength, great lightness, and ability to resist corrosion — emerged as the superior material for artificial legs. In Britain, Desoutter Bros. was the first company to be awarded a government contract to supply their metal leg to British ex-servicemen. Soon after, additional manufacturers of metal legs were also awarded contracts. Guyatt, "Better Legs," 315.
38. *Symposium on Prosthetic Achievement*, 24.
39. Dominion of Canada, Annual Departmental Reports 1926–27, Vol. 3, Department of Soldiers' Civil Re-establishment, Orthopedic and Surgical Appliances Division, *Annual Report 1926–27* (Ottawa: F. A. Acland, Printer to the King's Most Excellent Majesty, 1928), 29.
40. In 1921, the Desoutter Bros. metal leg (at £80) cost the British government four times the cost of the standard wooden leg. In 1926, the metal leg made in Toronto's metal limb shop cost $183.82, compared with the cost of a wooden leg at $59.18. Figures taken from Guyatt, "Better Legs," 316, and Canada, Annual Department, Reports 1926–27, 30.
41. *Symposium on Prosthetic Achievement*, 70.
42. United Limb & Brace Co., pamphlet, 1918, 4 pages, collection of the authors.

43. Ibid.
44. Ott, "Sum of Its Parts," 20.
45. Ibid.
46. Guyatt, "Better Legs," 321.
47. War Amps, www.waramps.ca/about/history.html (accessed November 22, 2007).
48. This section on the artificial kidney is taken from Shelley McKellar, *Surgical Limits: The Life of Gordon Murray* (Toronto: University of Toronto Press, 2003), 66–72, 90–2, and Shelley McKellar, "Gordon Murray and the Artificial Kidney Machine in Canada," *Nephrology Dialysis and Transplantation* 14 (November 1999): 2766–70.
49. See Steven J. Peitzman, *Dropsy, Dialysis, Transplant: A Short History of Failing Kidneys* (Baltimore: Johns Hopkins University Press, 2007).
50. The Hopkins artificial kidney machine was crude and dependent on hirudin — an anticoagulant extracted from leeches — to prevent blood clotting outside the body. Hirudin was difficult to work with and often toxic. The First World War interrupted the work of the Hopkins group, and there was little activity on dialysis in the interwar period that followed. One notable exception was German Georg Haas, who attempted the first human hemodialysis in 1924 as well as a second clinical case in 1925. His work showed promising but inconclusive results for the clinical use of the artificial kidney machine. Allen B. Weisse, "Turning Bad Luck into Good: The Alchemy of Willem Kolff, the First Successful Artificial Kidney, and the Artificial Heart," *Hospital Practice* (28 February 1992): 109–10. See also J. J. Abel, L. G. Roundtree, and B. B. Turner, "On the Removal of Diffusible Substances from the Circulating Blood by Means of Dialysis," *Transactions of the Association of American Physicians* 28 (1913): 51–4.
51. J. T. H. Connor, "Dutch Technological Migration and North American Commercial Exploitation: Dr. Willem Kolff and the Development of the Artificial Kidney," in *Connecting Cultures: The Netherlands in Five Centuries of Transatlantic Exchange*, ed. Rosemarijn Hoefte and Johanna C. Kardux (Amsterdam: Vu University Press, 1994), 281–303; W. Thalhimer, "Experimental Exchange Transfuction for Reducing Azotemia: Use of Artificial Kidney for This Purpose," *Proceeds of the Society for Experimental Biology and Medicine* 37 (1937): 641; Patrick T. McBride, *Genesis of the Artificial Kidney* ([Deerfield, Ill.?]: Baxter Healthcare Corp., 1987); J. Stewart Cameron, *A History of the Treatment of Renal Failure by Dialysis* (Oxford: Oxford University Press, 2002); James Kristian Koford, "High Technology in the Healing Arena: A History of the Artificial Kidney, 1913–1972" (dissertation, University of Utah, 2004).
52. See Gordon Murray's two-volume autobiography: *Medicine in the Making* (Toronto: Ryerson Press, 1960) and *Quest in Medicine* (Toronto: Ryerson Press, 1963).
53. William Thalhimer, "Experimental Exchange Transfusion for Reducing Azotemia: Use of Artificial Kidney for This Purpose," *Proceeds of the Society for Experimental Biology and Medicine* 37 (1937): 641–3.
54. Gordon Murray, Edmund Delorme, and Newell Thomas, "Development of an Artificial Kidney," *Archives of Surgery* 55 (November 1947): 505–22.
55. June Callwood, "The Amazing Mechanical Kidney," *Maclean's Magazine* (15 August 1949): 36. See also Murray, *Quest in Medicine*, 6.
56. As June Callwood correctly notes, "According to medical practice he [Murray] could not experiment on a human being until it had been established that he could do no harm because the patient was going to die in any case. Three sets of specialists certified this." See "Amazing Mechanical Kidney," 20.
57. Gordon Murray, Edmund Delorme, and Newell Thomas, "Artificial Kidney," *Journal of the American Medical Association* 137 (August 1948): 1596–99.
58. Murray found out the problem had been inadequate washing of the tubing. See Gordon Murray, Edmund Delorme, and Newell Thomas, "Artificial Kidney," *British Medical Journal* (22 October 1949): 890; David MacDonald, "The Woman in Ward F," *Reader's Digest* (March 1986): 64; Murray, *Quest in Medicine*, 8–9; Callwood, "Amazing Mechanical Kidney," 20–1; Greer Williams, "What You Should Know About Your Kidneys," *Saturday Evening Post* (28 January 1950): 32.
59. Murray, Delorme, and Thomas, "Artificial Kidney," *British Medical Journal*, 891; Murray, Delorme, and Thomas, "Artificial Kidney," *Journal of the American Medical Association*, 7–11; Murray, Delorme, and Thomas, "Development of an Artificial Kidney," 516–22.
60. Roy Greenaway, "Saves Life of Woman, 26, with Artificial Kidney," *Toronto Star* (20 December 1946); "Artificial Kidney Invented by Former Stratford Doctor," *Stratford Beacon Herald* (21 December 1946); "Artificial Kidney Saves Human Life," *Fort William Daily Times Journal* (21 December 1946); George Mann, "Artificial Kidneys Snatch Doomed Patients Out of Jaws of Death," *Toronto Star* (6 November 1948); Roy Greenaway, "Dr. Murray's Machine Restores 'Dead' Girl, Now She Is a Mother," *Toronto Star* (30 April 1949); "Sausage Casing Used as Kidney Saves Lives," *Toronto Star* (29 October 1949).
61. W. G. Cosbie, *The Toronto General Hospital, 1819–1965: A Chronicle* (Toronto: Macmillan of Canada, 1975), 258; Murray, Delorme, and Thomas, "Artificial Kidney," *British Medical Journal*, bottom of page 887.
62. C. F. Kemper to Murray, 6 January 1949, and F. J. Wallace (American Cystoscope Makers Inc.) to Murray, 26 October 1948, D. W. G. Murray, Papers, MG 30, B 110, Vol. 42, File 43, Library and Archives Canada. Also Chas. B. Ripstein to Murray, 27 February 1948, File 37; Edwin H. Brown (Allis–Chalmers Manufacturing Company) to Murray, 9 March 1949, and Solomon Goldenberg to Murray, 20 December 1949, File 28.
63. Murray to R. H. Goetz, 28 October 1948, Murray Papers, MG 30, B 110, Vol. 28, File 27.
64. Firms such as Westinghouse Corporation and the Allis–Chalmers Manufacturing Company constructed 3 and 15 artificial kidney machines, respectively, but abandoned production in the early 1950s because of cumbersome designs and expense. The Kolff–Baxter unit of 1956–57 was a better "product," cheaper, and market demand existed. Edwin H. Brown to Murray, 11 January 1951, Murray Papers, MG 30, B 110, Vol. 28, File 30; Connor, "Dutch Technological Migration," 281–303.
65. Willem Kolff is credited for the invention, building his artificial kidney in 1943; Nils Alwall in Sweden developed his machine in 1946; the American G. W. Thorn built one in the late 1940s. Murray Papers, MG 30, B 110, Vol. 35, File 5, Lecture Notes 1941–1949 [artificial kidney]; Connor, "Dutch Technological Migration," 281–303.
66. For more on Kolff's life, see Herman P. Broers, *Inventor for Life: The Story of W. J. Kolff, Father of Artificial Organs* (B&V Media Publishers, 2007); Paul Heiney, *The Nuts and Bolts of Life: Willem Kolff and the Invention of the Kidney Machine* (London: Sutton Publishing, 2003).
67. Murray, Delorme, and Thomas, "Development of an Artificial Kidney," 506.
68. For these differences, see McKellar, *Surgical Limits*, 70–1.

69. Renee C. Fox and Judith P. Swazey, *The Courage to Fail: A Social View of Organ Transplants and Dialysis*, 2nd ed. (Chicago: University of Chicago Press, 1978), 201–2.
70. The British medical community advised giving up the use of the artificial kidney in favour of a high-calorie, low-protein diet and a controlled fluid intake of a litre a day. Murray, Delorme, and Thomas, "Artificial Kidney," *British Medical Journal* (22 October 1949): 920–1. An editorial in the *Lancet* (February 1948) had reported that only 2 out of 15 dialysed patients had made complete recoveries. Taken from Connor, "Dutch Technological Migration," 281–303.
71. "Artificial Kidney Is Developed Here," *Montreal Gazette* (10 December 1946); "Second in Canada — Artificial Kidney in Use at VGH Saving City Man's Life," *Vancouver Sun* (6 November 1948); "Life-Saving Artificial Kidney Built Here," *London Free Press* (12 January 1949).
72. Connor, "Dutch Technological Migration," 281–303; J. T. H.Connor, "The Artificial Kidney in North America," *Biomedical Instrumentation & Technology* 23, no. 5 (September–October 1989): 384–7.
73. The exceptions were Conrad Lam and Joseph Ponka, who experimented with the original Murray artificial kidney machine in Detroit, and the Brazilian doctor Tito Ribeiro de Almedia, in Sao Paulo.
74. Callwood, " Amazing Mechanical Kidney," 21.
75. Ethel Kerr to M. Wilson, 27 February 1961, Murray Papers, MG 30, B 110, Vol. 41, File 16.
76. William Clarke, "A Canadian Giant: Dr Gordon Murray and the Artificial Kidney," *CMAJ* 137, no. 3 (August 1987): 247.
77. Dr G. G. Caudwell, interview with Shelley McKellar, 13 November 1996, Hamilton, Ontario.
78. Callwood, " Amazing Mechanical Kidney," 21.
79. Murray to Doros Oesconomos, 14 March 1952, Murray Papers, MG 30, B 110, Vol. 28, File 31.
80. W. P. Caven Memorial Research Foundation, Annual Report, 1952, Murray Papers, MG 30, B 110, Vol. 47, File 31; Murray to Ian Paiton, 8 April 1952, Vol. 28, File 31; William W. Allis to Murray, 25 January 1951, Volume 28, File 30.
81. L. T. Skeggs and J. R. Leonards, "Studies on an Artificial Kidney: Preliminary Results with a New Type of Continuous Dialyzer," *Science* 108 (1948): 212–3; A. G. McNeill, "Blood Dialyzer Design," *Bulletin of Cardiovascular Disease* (1953): 173–7.
82. W. P. Caven Memorial Research Foundation, Annual Report, 1955, Murray Papers, MG 30, B 110, Vol. 47, File 31.
83. "Artificial Kidney" in Freilbourg Clinic [newspaper clipping], *Suedkurier* (15 February 1954), English translation, Murray Papers, MG 30, B 110, Vol. 42, File 43. It is unknown when Murray read this clipping. Also Vol. 39, File 12, Artificial Kidney notes and correspondence — Roschlau provided Murray with an English summary of German H. Sarre's articles "The Treatment of Acute Toxic Kidney Insufficiencies" and "The Artificial Kidney and Other Extrarenal Detoxication Processes for Treatment of Anuria and Uraemia," dated 9/7/54. Footnote regarding the artificial kidney as used by Sarre: "Gratitude is expressed towards the German Research Community for making available the so-called artificial kidney which has been built by engineer Halstrup in cooperation with us."
84. Clarke, "Canadian Giant," 247; Dr Walter Roschlau, interviews with Shelley McKellar, 17 April and 24 July 1996, Toronto.
85. Cosbie, *Toronto General Hospital*.
86. Ott, "Sum of Its Parts," 25.



CHAPTER 8

Monitoring, Measuring, and Intervening Against Heart Disease

Monitoring, Measuring, and Intervening Against Heart Disease

Heart disease is a prominent cause of death in affluent nations. In the United States and Canada, it has been the number one killer every year since 1900 (except 1918). In fact, cardiovascular disease claims almost as many lives each year as the next five leading causes of death combined.[1] In Canada, almost 79,000 people died of heart disease in 1999 and more than 80 percent of Canadians (age 20 to 59 years) have at least one risk factor for heart disease or stroke.[2] According to the Heart and Stroke Foundation, the total cost of heart disease and stroke to the Canadian economy in 1997 was approximately $18.5 billion, more than any other disease.[3]

In the early years of the century, the medical community could treat only the symptoms of heart disease. Doctors offered digitalis to treat heart failure, oral diuretics to fight fluid retention brought on by heart failure, and, from the 1930s, prostaglandin to lower blood pressure.[4] By mid-century, new surgical procedures had been introduced that successfully corrected numerous congenital and acquired heart disease conditions. Since the Framingham Heart Study of 1948, the emphasis has shifted to prevention, with research suggesting that heart disease can be controlled through exercising, not smoking, and eating the right foods.[5]

Heart disease includes all the disorders that can affect any part of this organ, such as the heart tissue, chambers, valves, coronary arteries, and nodes. The most common causes of morbidity and mortality are coronary artery disease and cardiac arrhythmias. When the coronary arteries become clogged and then narrow, they can fail to deliver the required oxygen to the heart muscle, particularly during stress or physical activity. The danger in coronary artery disease is that the accumulation of plaque (fatty deposits adhering to the wall of the artery) will progress to the point where the coronary artery is clogged completely and no blood is delivered to that part of the heart serviced by the artery. The result is a myocardial infarction (commonly called a heart attack). In contrast, individuals suffering from cardiac arrhythmias have a heart that beats either too fast (tachycardia) or too slowly (bradycardia). An irregular heartbeat interferes with the contractions of the heart muscle to pump deoxygenated blood to the lungs and to pump oxygenated blood to the body. When the contractions of the heart muscle become unsynchronized, the heart is no longer able to pump blood effectively. In some cases, the pulses to the heart are blocked altogether (referred to as "heart block") and the heart becomes inefficient at pumping blood. Congestion of blood in the heart and lungs occurs, which results in congestive heart failure and/or pulmonary edema.

In the nineteenth and twentieth centuries, decades of heart research involving animals and patients have been devoted to learning heart anatomy, physiology, and dysfunction for the purpose of treating heart disease. Canadian researchers and physicians alongside others have contributed to medicine's knowledge of the heart as well as the ability to treat heart disease.[6] The history of the tools physicians used to diagnose and treat heart disease highlights the history of heart disease in the late 1800s and first half of the twentieth century. Physicians gained knowledge about heart function through use of the stethoscope, by a variety of pulse-recording devices, and with the electrocardiograph. Surgeons quickly adopted the invasive diagnostic procedure of cardiac catheterization and angiocardiography to detect heart defects and obstruction. To treat heart disease, surgeons also explored bold surgical procedures and experimented with external artificial pacemakers. Yet despite improved diagnostic and therapeutic tools, heart disease remains the number one killer in Western industrialized nations.

Understanding Heart Function and Disease

Modern understanding of heart function and disease dates back to the English physician William Harvey (1578–1657), who contributed to a new perception of human physiology with his treatise *On the Motion of the Heart* (1628). Before this, the Greek physician Galen's doctrine of medicine had dominated for fifteen centuries. According to Galen, the heart served only to warm the blood, which did not travel through the body. Harvey argued that the heart functioned as a pump in a larger system of blood circulation. Through his scientific experiments, Harvey showed that the heart was a muscle with regular contractions that drove the blood through the body in a continuous process of circulation. Its beat was due to the muscular contraction. The valves of the heart were so arranged that the blood could be expelled in only one direction through the arteries. As his experiments showed, the heart sent a continuous and rapid stream of blood into the arteries, and that same blood returned from all over the body in the veins.[7]

Harvey's theory of blood circulation was later proven correct with further study of human anatomy. The heart is a hollow, muscular cone-shaped organ, about the size of a closed fist, lying between the lungs. It consists of four chambers: the right and left atria on the top and the right and left ventricles at the bottom. The chambers are enclosed in three layers of tissue: the epicardium (outer layer), the myocardium (middle layer), and the endocardium (inner layer). Surrounding the entire organ is the pericardium, a thin layer of tissue that forms a protective covering for the heart. The heart also contains various nodes that transmit electrochemical signals, causing heart muscle tissue to contract and relax in the pumping action that carries blood to organs and cells throughout the body. Signals from the brain cause the heart to contract rhythmically in a sequence of motions that move deoxygenated blood from the right side of the heart into the lungs. The newly oxygenated blood returns from the lungs to the left side of the heart, which contracts forcefully to pump this blood out to the body to nourish tissues and cells. The heart valves control the direction of the blood as it flows through the heart and lungs. Like any working muscle, the heart needs a good supply of oxygen and nutrients. Coronary arteries encircle the heart to nourish the heart muscle with oxygenated blood.[8]

Understanding the anatomy of the heart and its role as a pump helped to explain many of the vital functions of the heart. But what were the conditions responsible for its malfunction? Why did the heart run more swiftly at some times than others? Physiologists and medical men developed and utilized a variety of instruments and technologies to aid in their diagnosis and treatment of heart disease.

In 1819, René Laennec (1781–1826) invented the stethoscope, an instrument for amplifying the sounds in the chest or other parts of the body. These noises created by the heart were described by Laennec as "rales, crepitations, murmurs, pectoriloquy, bronchophony, egophony."[9] For example, the first heart sound is a dull thud as the ventricles, having filled, begin to contract, their inlet valves close, and blood begins to flow into the arteries. The second sound is sharper; it is heard when the ventricles have emptied themselves and the outlet valves close. A disorder of the valve causes added sounds, such as a murmur or *bruit*. Laennec's and other researchers' extensive classifications of the "sounds" were correlated with autopsy reports. Thereafter, the stethoscope served to greatly aid physicians in their diagnosis.[10]

Another way to examine heart function was through the pulse. Physicians sought to measure the rate and rhythm of the pulse to distinguish between normal and abnormal circulation and then to link this information to the function of the heart muscle. During the nineteenth and early twentieth centuries, various instruments and devices were developed to provide physicians with a visual form of pulse measurement.

Measuring and Monitoring the Circulation of the Blood: The Sphygomometer, Sphygmograph, Sphygmomanometer, and Polygraph Machine

When researchers first tried to measure blood pressure in animals in the early 1700s, they cut into arteries and inserted narrow columns of glass that were marked in millimetres and were partially filled with mercury, which bobbed up and down in time to the heart's beating.[11] Because this technique was dangerous and unsuitable for human subjects, researchers then began to work on constructing pulse-measuring instruments that did not require breaking the skin. Since that time, numerous pulse-related instruments that measure the volume, strength, and frequency of the pulse have emerged, including the sphygomometer, sphygmograph, sphygmomanometer, and polygraph.

The Sphygomometer and Sphygmograph

Introduced in the nineteenth century, the sphygomometer and later sphygmograph were used to measure the force of the pulse. Initially developed as research tools by physiologists interested in studying heart rate, these devices were later adopted by physicians as important diagnostic tools to indicate potential heart conditions. (For example, a consistently high heart rate suggests tachycardia while a consistently low heart rate denotes brachycardia, both possible indicators of more serious heart disease.) The sphygomometer was one of the first pulse amplifiers that could be applied without opening an artery. Invented by Jules Herisson and constructed by the engineer Paul Germiner in 1834, it provided a measurement of the volume, strength, and frequency of the pulse but did not provide a permanent record of these measurements.[12] As described by the medical sciences curator Audrey Davis, the sphygomometer consisted of "a straight glass tube, filled with mercury and covered at the other end with an elastic membrane. The mercury moved vertically in response to the movements of the artery."[13] These early sphygomometers were clumsy and undependable, and were not immediately adopted by the medical profession.[14]

The sphygmograph was a pulse recorder introduced by Étienne-Jules Marey (1830–1904) in 1860. It magnified the movement of the pulse, provided a continu-

ous record of the strength and rate of the beats, and transferred the beat onto paper. As described by Davis, "Marey's sphygmograph consisted of a long spring furnished with a pelotte or button to be fastened over the radial artery [in the forearm]. The spring's motions were communicated to a lever approximately six inches long, furnished with a stylus or pen that traced the movements on a strip of smoked paper or glass, which was moved by a clock mechanism underneath the pen."[15]

Marey's sphygmograph extended up the arm longitudinally and was difficult to use. Clinicians only became interested in the machine when it became smaller, easier to use, and more accurate. The sphygmograph underwent numerous modifications, with the most successful changes made by the homeopathic physician Robert E. Dudgeon. Dudgeon's sphygmograph, introduced around 1882, was smaller and applied only to the wrist. As described by Davis, "Dudgeon's sphygmograph measured two and a half by two inches and weighed four ounces. A hand-wound clockwork [mechanism] pulled a piece of smoked paper six inches long by an inch in height through the instrument in ten seconds. The smoked paper record was varnished with gum dammar in bezodine to preserve its tracing."[16]

Both the sphygomometer (which measured the pulse) and the sphygmograph (which recorded the pulse on paper) were pulse recorders used first by researchers to explain the physiology of circulatory disease and then later by clinicians to identify circulatory anomalies or disease in their patients. There is no reason to believe that Canadian physicians responded differently than American or British medical men to these devices, although secondary sources on Canadian practice are slight.[17]

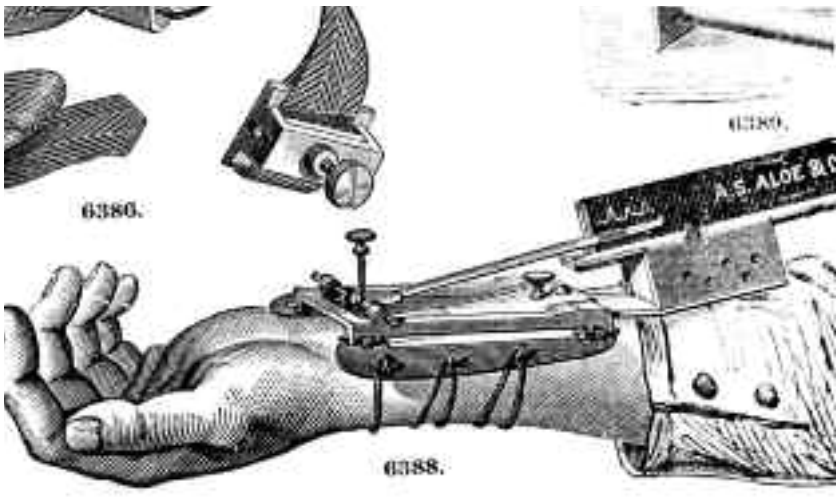


Figure 40. *The Marey sphygmograph was a pulse recorder used first by researchers to explain the physiology of circulatory disease and then later by clinicians to identify circulatory anomalies or disease in patients.*

(*A. S. Aloe Catalogue*, 351, courtesy of the Smithsonian's National Museum of American History, Behring Center, Washington, D.C.)

The Kymograph and the Sphygmomanometer

The diagnostic technique of measuring blood pressure was introduced in the nineteenth century and more fully developed in the twentieth century. Blood pressure is the pressure of blood against the walls of the main arteries. Pressure is highest during systole, when the ventricles are contracting (specifically when the right ventricle is expelling deoxygenated blood into the lungs and the left ventricle is expelling oxygenated blood throughout the body), and lowest during diastole, when the ventricles are relaxing and refilling with blood. Blood pressure is measured in millimetres of mercury by means of a sphygmomanometer at the brachial artery of the arm, where the pressure is most similar to that of blood leaving the heart.

If exact measurement and quantification, and the recording of data, underlay physiology, then its seminal instrument, according to Merriley Borell, was the recording drum kymograph. The German physiologist Carl Ludwig invented this blood pressure recording device in 1846. On top of a mercury manometer (a device that measures pressure), he mounted a float with a rod and quill pen attached. As the pressure changed, the quill moved up and down and left a mark on graph paper attached to a rotating drum. "The height of the mercury, which previously could only be estimated by eye and which wobbled as the experimental animal's blood pressure varied, could now be measured precisely from the kymograph tracing."[18] Sphygmomanometers are also instruments that measure the pressure of the circulating blood.

The Austrian physician Samuel Von Basch developed one of the earliest sphygmomanometers in 1880. According to Davis, "It consisted of a thick-walled glass tube containing mercury which opened out into a small knob connected to a membranous bulb filled with water. This 'pelotte' was placed on the artery until the pulse was obliterated."[19] While the sphygmomanometer was useful to physiologists, most clinicians found it too difficult to operate. Various refinements were required to make the instrument more compact, portable, user-friendly, and accurate.

The first clinical sphygmomanometer to be used widely (which remains the

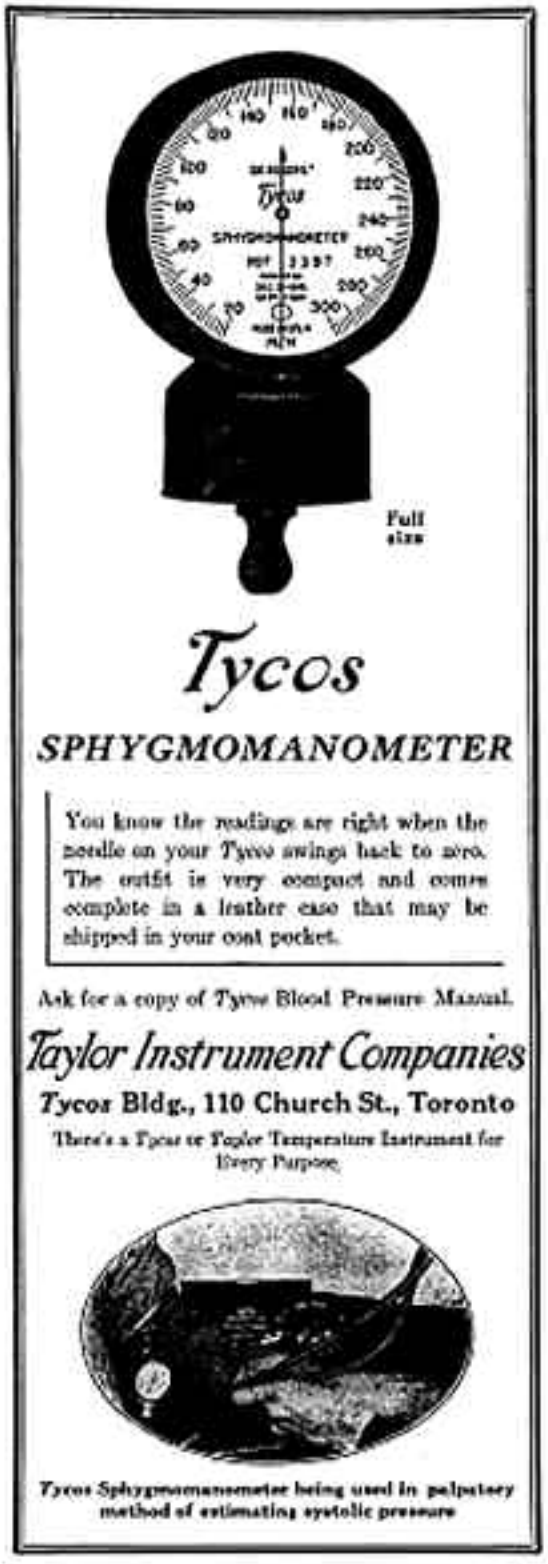


Figure 41. *Medical apparatus was sold to practitioners through physician supply companies and marketed in medical journals. This 1925 advertisement for a Tycos sphygmomanometer describes a compact portable blood pressure device suitable for house calls and offers a training manual with photographs of correct usage.*

(*Canadian Medical Association Journal* 15, no. 9 [September 1925]: xxi)

blood pressure instrument used by doctors today) was developed in 1896 by the Italian physician Scipione Riva-Rocci (1863–1937). Riva-Rocci improved compression of the artery by using a thin rubber tube five centimetres wide to encircle the upper arm, thereby giving a uniform pressure over a wider area. In 1901, Leonard Hill and Harold Barnard attached in place of the mercury tube an aneroid (that is, using no liquid) manometer with a cuff, 12 to 14 centimetres wide, which provided even more accurate readings. The flexible, hollow cuff is inflated until air pressure inside it matches the blood pressure in the patient's arm. As the cuff deflates, the physician listens to the beat of the pulse via a stethoscope while the blood pressure is read from a dial. By 1920, the most popular portable manometer was one invented by Dr Oscar H. Rogers, chief medical director of the New York Life Insurance Company.[20] Audrey Davis argues that the sphygmomanometer was one of several diagnostic instruments that life insurance companies embraced to set physiological standards in the gauging of length of life.[21]

The life insurance industry figures prominently in the development of blood pressure measurement and meaning. The sector quickly adopted, even pioneered, the evaluation of individuals against the "normal," and it depended on physiological medical technology in the process.[22] Over decades of experience and the accumulation of data, physicians and researchers associated with life insurance companies determined the tests and instruments that were most useful predictors of likely life span. Beyond instruments that detected lung disease, discussed in chapter 3, life insurance doctors relied on a patient's blood pressure as measured by the sphygmomanometer. Life insurance companies also promoted the idea of the physical examination for the healthy patient (or for the patient who pretended to feel well, the life insurer's nightmare). Urinalysis against possible undiagnosed kidney trouble, and later the endoscope and the X-ray, were added to the examination. Physical standards of health were thus set by life insurance companies, which compiled data from thousands of clients because they needed basic measurable parameters of good health.[23]

These standards were also applied to groups and individuals beyond potential life insurance clients. Doctors surveyed the British, American, and Canadian armies in the First World War; the results distressed the military and civilian health authorities because they revealed high levels of tuberculosis, venereal disease, and generally substandard health, and in the process, confirmed some middle-class suspicions about lower-class inferiority. The future of the economy seemed at risk. As the Honorary Advisory Council for Scientific and Industrial Research reported in 1920, industrial fatigue was "associated very intimately with the health and diet of the worker and hygienic conditions or

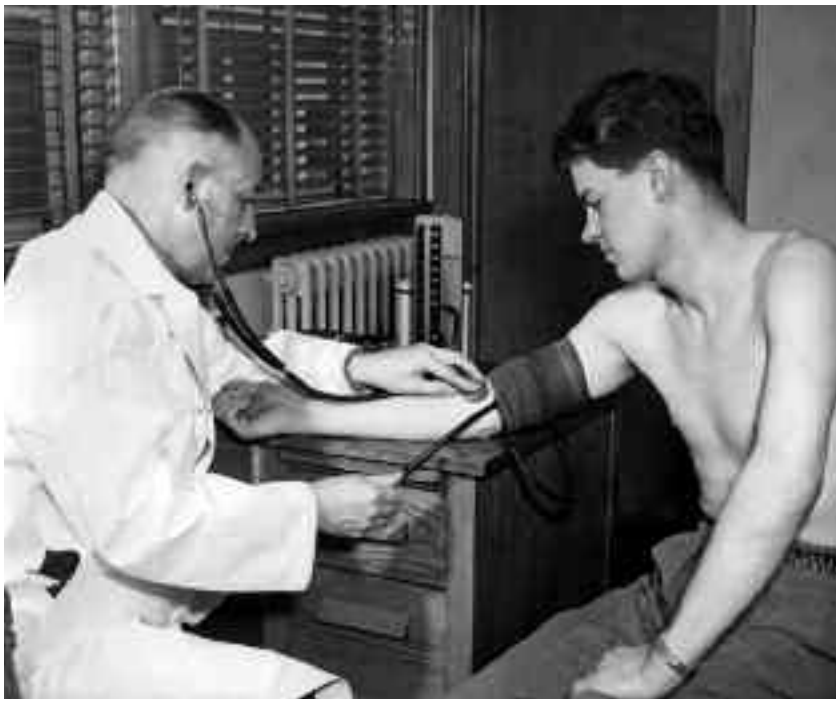


Figure 42. *The Canadian National Railway Company operated medical clinics, such as this one in Moncton, New Brunswick, for its employees. Blood pressure instruments used today are not that different from the first clinical sphygmomanometer, developed in 1896 by the Italian physician Scipione Riva-Rocci.*
(CSTM/CN Collection)

otherwise of his environment."[24] The premium placed on quantifiable and standardized data, especially blood pressure readings, had strong consequences for social relations, particularly for creating or reinforcing powerful ideas about gender, class, and race.[25] Numbers and standards led to new classifications and groupings. One example is the development of the idea of "normal," and concomitantly, "abnormal."

The "normal" North American blood pressure for decades was based on measurements taken about 1914, but the accumulation of data by 1952 indicated that a more accurate "average" was a higher reading.[26] Today, observers in and out of medicine accept that physiological "laws" and measures of normalcy are relative, shaped by their social and cultural context.

James Mackenzie and the Polygraph

The English physician James Mackenzie (1853–1925) promoted the polygraph as a research tool to understand heart sounds and changes in rhythm. The polygraph provided a diagrammatic representation of the variations of the simultaneous pulsing cycle in the arteries, veins, and heart. The machine recorded cardiac pulsations first by two tambours, which wrote on a smoked drum, and which were later modified for ink-writing. The polygraph machine could be used to record a patient's heartbeat and pulse for up to one and one-half hours.[27]

From these recordings, Mackenzie explained common disturbances of the heartbeat (or arrhythmia) in his book *Diseases of the Heart* (1908). He described various heart sounds and changes in rhythm, classifying them into normal and abnormal categories, and identified those indicative of heart disease and those that were harmless. According to the cardiologist Harold Segall, a few Canadian physicians used the Mackenzie polygraph in private practice and in hospitals during the 1920s.[28] Not all physicians, however, agreed with Mackenzie's classification or categorization of harmless rhythms.[29] Nor did they concur with Mackenzie's criticism that medical instruments were being overused so that physicians were losing their skills to detect disease at earlier stages. In Mackenzie's view, improving instruments was not the means to better medical practice.[30] He believed that detecting heart rhythm or pulse irregularities in a patient could just as easily be achieved by the classic methods of inspection, auscultation, and percussion without instruments. However, Mackenzie accepted that instrumentation contributed to research studies investigating aspects of disease. Mackenzie's work with the polygraph, and its potential contributions to studies of heart function, was overshadowed by the success of Willem Einthoven's electrocardiograph.

Measuring and Monitoring the Electrical Pulses of the Heart: The Electrocardiograph

In 1903, the Dutch physiologist Willem Einthoven (1860–1927) invented the electrocardiograph (ECG in Canada, EKG in the United States), an apparatus centred on a refined string galvanometer that recorded the electric activity of the heart.[31] Galvanometers measure and amplify electrical signals being transmitted between locations. Einthoven developed a very sensitive galvanometer that consisted of a coil of fine wire, silvered to reflect a beam of light, which was deflected by the passage of a fluctuating current in a powerful magnetic field. The recording of the light reflected from the string was on a moving glass photographic plate, later on a roll of photographic paper, both of which were developed to produce the

image. A more detailed description is taken from a specialized cardiology textbook of the period:

> *The moveable part is a microscopic thread of quartz called a "string," which is suspended vertically in a strong magnetic field. When a minute current is passed through it, the "string" is deflected, or really bent laterally. As the string is supported at both ends, has a very small mass, and moves only a fraction of a millimeter, it has very little inertia, and can record impulses up to many hundred times per minute. These records are obtained by making the string opaque with a coating of silver, placing it in a beam of light which throws a vertical shadow, magnified by a microscope, onto a metal plate in which there is a horizontal slot. This slot allows only a point of shadow to pass through to a moving photographic plate or film, on which the point of shadow writes in a continuous curve.*[32]

Figure 43. *This electrocardiograph (ECG), manufactured by General Electric, includes a rolling stand, battery case, and amplifier unit. The ECG has become one of the most widely used diagnostic tools.*

(Courtesy of the Smithsonian's National Museum of American History, Behring Center, Washington, D.C.)

Einthoven's string galvanometer was sufficiently sensitive to detect the extremely small electrical events generated by the heart. The signals were obtained from the two arms and the left leg. To enhance conduction, the patient's hands and left foot were placed in tubs of saline solution.[33] By the 1930s, contact electrodes — metal disks with wire leads that were strapped to the wrists and ankles of the patient — had begun to replace the electrolyte baths.[34] Today, the wire leads are attached to disposable patches that are laminated and self-adhesive.

With the electrocardiograph, Einthoven tracked variations in the heartbeats of his patients. He later defined the meanings of the changes in the heart's patterns of electric current. He learned what constituted a normal heartbeat and linked abnormal readings with specific kinds of heart disease. Through these tracings, physicians could detect disturbances of the natural rhythm of the heart, thickening of the heart walls as well as damage to the heart muscle.[35] As noted by Jacalyn Duffin, the electrocardiograph "refined the clinical diagnosis of angina and myocardial infarction. Previously detected only at autopsy and debated even then, myocardial infarction emerged from a vague set of earlier diagnoses, including acute indigestion and apoplexy."[36] In 1924, Einthoven was awarded a Nobel Prize for his invention.[37]

The first electrocardiograph arrived in the United States from a German manufacturer in 1909.[38] In Canada, the Toronto General Hospital, the Montreal General Hospital, and Vancouver General Hospital all acquired electrocardiographs in 1914. At $1,100, the machine was expensive and hospitals depended on donations for its purchase.[39] In some

places where universities had purchased electrocardiographs as research tools, physicians sent patients to the physiology laboratories for testing. In Toronto and Montreal, John Oille and Thomas Cotton, respectively, used the electrocardiograph in practice at their respective hospitals and in teaching, which contributed to the fledgling specialty of cardiology. In Montreal, technical difficulties plagued the initial use of this new technology; the hospital laundry needed to be stopped before using the electrocardiograph due to electrical interference.[40]

Compared to the adoption of the X-ray, most clinicians did not immediately recognize the utility of the electrocardiograph as a diagnostic tool.[41] In the majority of Canadian hospitals, the electrocardiograph was not introduced until the 1920s and 1930s.[42] Einthoven's first electrocardiograph (which comprised the string galvanometer, an arch lamp, the projecting system, a timing system, and the falling glass plate camera) weighed about 600 pounds and required five people for its operation. It was cumbersome and expensive. Several companies redesigned the machine to make it more marketable. The first popular model was the table electrocardiograph manufactured by the Cambridge Scientific Instrument Company in London, England. By the mid 1920s, smaller portable electrocardiographs were manufactured by the Cambridge Instrument Company of New York. By the mid-twentieth century, the string galvanometer for electrocardiography was superseded by more compact units using first vacuum tubes and later batteries.[43]

The electrocardiograph has become one of the most widely used diagnostic tools. Using an ECG, physicians can measure deviations in the normal height, form, and duration of the wave patterns that illustrate the heart's electric pulses on a screen. As Einthoven discovered, these changes can indicate specific disorders. ECGs can be taken while the patient is exercising, revealing differences between the oxygen levels in the blood supply and demonstrating the heart muscle's oxygen requirements. By taking an ECG of patients under stress, physicians can see if the circulatory system is able to meet the heart's increasing demand for oxygen as it works harder. This information can indicate the chances of a heart attack.

An Invasive Diagnostic Procedure: Cardiac Catheterization and Angiocardiography

Cardiac catheterization is the use of a cannula or tube threaded through an arm vein and into the heart to collect blood samples from various parts of the circulation system or to measure pressures in the heart and arteries. Besides the kymograph, the earliest application of cardiac catheterization was in the diagnosis of some congenital heart diseases by showing abnormalities in the structure of the heart and abnormal pressures in circulation. Today, cardiac catheterization is often combined with angiocardiography or contrast radiography of the heart and blood vessels. Angiocardiography is a procedure by which a liquid containing a radiopaque substance, which shows up when X-rayed, is introduced into the blood. Whereas electrocardiography is a non-invasive technique, cardiac catheterization and angiocardiography are invasive procedures that surgeons utilized almost immediately to assist them in their diagnosis of heart defects and planning of repair.[44]

Beginning in the mid-nineteenth century, several European researchers experimented with the insertion of catheters into the blood vessels of animals or dying human beings for the purpose of diagnosing heart function problems. In 1929, Werner Forssman (1904–1979) performed the first successful cardiac catheterization by inserting a catheter designed for insertion into the urinary tract into a vein in his own arm and directing it into the right side of his heart. Apparently without discomfort, Forssman walked to the X-ray department of his own hospital, with the catheter in place, to have an image taken. Forssman also investigated ways to inject radiographic contrast material through a catheter into the heart to permit X-ray images.[45]

During and after the Second World War, André Cournand (1895–1988) and others at Columbia University successfully transformed cardiac catheterization from a research laboratory experimental method into a diagnostic tool for clinicians. They refined the procedure and demonstrated its utility for evaluating both normal and abnormal heart function in patients. The urological catheter was replaced with a more flexible catheter that could be inserted more easily into the arm and advanced through the venous system into the heart and as far as the pulmonary artery leading into the lungs. Critics warned that the body would react against the insertion of this foreign object, by blood clotting along the catheter or a rise in the respiration and heartbeat of the patient. This was not the case. Cournand and his research team demonstrated that cardiac catheterization was safe and extremely useful in providing reliable information about blood pressure and blood flow within the heart. Physicians could now measure the pumping efficiency of the heart and the adequacy of blood circulation in their patients. Cardiac catheterization became a widely practised diagnostic procedure in hospitals by the late 1940s, and by the 1950s it was a standard routine for patients undergoing heart surgery.[46]

Treating Heart Disease: Cardiac Surgery and Pacemakers

In the twentieth century, drugs constituted the dominant treatment for heart disease. Various drugs were prescribed to improve heart contraction, reduce heart work, and protect against blood clots. For the treatment of chronic heart failure, digitalis, a derivative of the foxglove plant, was the most frequently used inotropic drug (able to increase the contractile ability of the heart muscle). Discovered by William Withering in the mid-eighteenth century, digitalis increased calcium levels within the heart muscle cells, thus improving heart muscle contraction.[47] More recent twentieth-century drugs used to increase calcium levels within the heart muscle cells include dopamine, terbutaline, and levodopa. These drugs, however, have serious side effects: increased heart rate, palpitations, and nervousness. Vasodilator drugs (such as hydralazine, pinacidil, dipyridamole, and the nitrates) act to decrease the work of the heart by allowing for the expansion of blood vessels, making it easier for blood to be pumped through them. Antithrombotic drugs (blood clot inhibitors), including heparin and aspirin, attempt to prevent obstruction of the circulation with blood clots. Clots can lodge in the heart, where they can cause damage to the heart muscle, or in the brain, where they can cause a stroke. Drug therapies rarely reversed damage to the heart, but they permitted patients to live in greater comfort.[48]

Cardiac Surgery

In the first half of the twentieth century, a small number of researchers began investigating ways (1) to repair the heart surgically and (2) to develop a device to regulate the beating of the heart.[49] Until the twentieth century, the heart was considered off-limits to the surgeon's scalpel. A few daring nineteenth-century surgeons may have sutured puncture wounds or drained the pericardium (the sac around the heart) to relieve chest pain, and in a few exceptional cases, foreign bodies lodged in the walls of the heart may have been removed. But patients rarely recovered from such injuries. This discouraged most surgeons from operating, and the profession thought that wise. In the 1880s, Theodor Billroth of Vienna, one of the world's most prestigious surgeons, stated, "Any surgeon who would attempt an operation on the heart should lose the respect of his colleagues." Similarly, in 1896, Sir Stephen Paget of London declared, "The heart alone of all viscera has reached the limits set by nature to surgery. No new method and no new technique can overcome the natural obstacles surrounding a wound of the heart."[50]

In addition to technical difficulties, different ideological understandings of the heart also inhibited the development of cardiac surgery. For example, the rise of the "new cardiology" in Britain at the beginning of the twentieth century displaced the surgeon from treating heart disease. Previously, diagnosis and treatment had focused on the anatomy and mechanics of the heart. The newer concept of the "living heart" shifted the clinician's focus to the physiology and dynamics of the heart. Diseases of the heart were defined as medical and were increasingly treated with drugs rather than surgery. Chest surgeons, of course, challenged the concepts of the new cardiology, for they remained focused on anatomical lesions, such as diseased valves, as the fundamental cause of heart problems. The new cardiologists responded that valve surgery did not treat what was basically wrong, the functioning of the heart muscle.[51]

British, American, and Canadian surgeons forged ahead with new operations but had limited success. In 1925, the British surgeon Henry Souttar of London successfully performed a controversial procedure to treat a closed heart valve (mitral stenosis). Souttar's patient survived the operation and even showed some improvement. Nevertheless, British cardiologists refused to refer any more patients to Souttar, and he was never given the chance to repeat the operation. During the 1920s, both before and after Souttar's publicized case, the American surgeons Elliott Cutler, Claude Beck, Evarts Graham, Duff Allen, and others explored numerous heart valve procedures without success. In the 1930s, the Canadian Gordon Murray developed a vein graft procedure to treat mitral stenosis. However, only a few patients who underwent the experimental operation enjoyed improved health after the surgery.

Heart surgeons did not experience any real success until the celebrated blue baby operations of the mid 1940s.[52] "Blue babies" are children born with malformed hearts, specifically holes in the interior heart walls, open fetal ducts, transposed heart vessels, or obstructed heart valves. Prevented from properly circulating through the heart and into the lungs to be replenished with oxygen, deoxygenated blood is recirculated through the body, causing cyanosis — the child's skin, lips, and fingernails turn blue because of insufficient oxygen in the blood. Blue babies may suffer unusual murmurs or thrills of the heart, a slow or stunted rate of growth and development, and an alteration in the size, shape, and/or position of the heart. As blue babies age, they suffer increasing shortness of breath, spells of unconsciousness, and respiratory distress from oxygen deprivation. Prior to the mid-twentieth century, few blue babies lived to adulthood. Physicians could offer only palliative medical treatment of rest, oxygen, heart medication, and sometimes diuretics.

In 1936, the Canadian doctor Maude Abbott of McGill University published the *Atlas of Congenital Cardiac Disease* based on one thousand cases, and in 1947, the American cardiac paediatrician Helen Taussig at Johns Hopkins University wrote the first comprehensive textbook on the subject, *Congenital Malformations of the Heart.*[53] As physicians like Abbott and Taussig were improving the profession's ability to diagnose congenital heart conditions, several surgeons were working towards offering surgical treatment for these patients in a way that had never been attempted before — by operating on a beating heart.[54] More precisely, these surgeons predominantly operated on the great vessels of the heart (arteries leading away from the heart) in an attempt to repair or compensate for heart malformations. The American cardiac surgeons Robert Gross and Alfred Blalock both developed new procedures, as did Gordon Murray, which were successful in saving the lives of many blue babies.[55]

Gordon Murray emerged as Canada's famed blue baby doctor.[56] In the five-year period between 1946 and 1951, Murray performed almost six hundred operations. He operated on infants, children, and adults, their ages ranging from ten months to forty-three years.[57] He lost fewer patients than almost any other surgeon who operated on the heart. Dr M. E. J. Stalker stated: "I don't know of anyone else in Canada who could attempt such an operation. It takes not only great surgical skill but also great courage and an outstanding knowledge of anatomy."[58] Dr John Scott said, "It was known that he was technically outstanding; and that he would try things and succeed where others would hesitate even to attempt it."[59]

In Canada and the United States, successful cardiac surgery generated enormous media attention. In this period of emerging specialized journalism, reporters who were not medically trained themselves strove to present correct and detailed information to the public in an effort to keep society abreast of medical change. Physicians and hospital administrators, initially reserved, soon began to enjoy the publicity, especially the celebrity, which the glowing news reports created; they recognized the potential value of "success stories" both professionally and financially. Everyone enjoyed a good medical success story, particularly these blue baby operations that delivered miracles. Medical reporting in this period was celebratory and uncritical, turning heart surgeons into heroes.[60]

By the late 1940s and increasingly into the 1950s, there was no doubt that heart surgery was the new exciting field. In the mid 1950s, the field of heart surgery underwent a transformation. Technological innovations began to alter dramatically how surgeons operated on the heart. This was the beginning of open-heart surgery. Surgeons were exploring methods by which they could open the chest and, under direct vision, perform more complex corrective cardiac operations on a quiet, bloodless heart. The Toronto surgeon Wilfred G. Bigelow introduced hypothermia, a surgical technique involving total body cooling. Bigelow's idea was to "cool the whole body, reduce the oxygen requirements, interrupt the circulation,"[61] and then open the heart. In 1952, John Lewis used the open-heart hypothermia technique in Minneapolis and successfully operated on a blue baby. The hypothermia technique allowed surgeons to cut off blood circulation from a beating heart for eight minutes, providing a bloodless field and direct vision in which to correct heart anomalies. However, this small eight-minute window, the time during which the heart could be stopped without affecting the brain, limited the surgeon to simple cardiac operations.

Several other investigators were experimenting with methods of extracorporeal circulation that would extend the operating time of the surgeon. Most promising were the heart-lung machines being built by Clarence Crafoord in Sweden, by J. Jongbloed in Holland, and by John Gibbon Jr in the United States. It was a steep technological challenge to remove the blood from the body, oxygenate it, and return it without damaging its properties. Tubes were inserted in the patient's blood vessels leading into and away from the heart, redirecting oxygen-poor blood going into the heart to the machine. The machine then pumped the blood to an oxygenator, replicating the functions of the lungs by removing carbon dioxide and adding oxygen. The blood was then pumped through a filter to remove clots and bubbles before it was returned to the patient.

In 1953, Gibbon successfully operated on a blue baby using his heart-lung machine.[62] Improvements in the pump were needed, but Gibbon had shown that his procedure was possible. Within a few years, surgeons and medical researchers succeeded in modifying technical aspects of the machine and the surgical procedure. For example, Crafoord's, Jongbloed's, and Gibbon's heart-lung machines all worked on the same operating principle, but they had different oxygenators. John Kirklin at the Mayo Clinic modified the Gibbon machine, and the inexpensive, easily assembled DeWall bubble oxygenator (or Lillehei pump oxygenator) became available after that. In Toronto, Bigelow continued his research on hypothermia and William Mustard experimented with monkey lungs at the Hospital for Sick Children in developing techniques for open-heart surgery.[63] Mustard commented that this was "the golden era of heart surgery in which I was fortunate to be in at the beginning. So that's how I became a cardiac surgeon. I just fell in love with it, that's all. It was so exciting and the time was so exciting."[64] Both Bigelow and Mustard would later

convert to mechanical extracorporeal systems with which to perform open-heart operations. By the late 1950s, heart surgeons almost everywhere were performing cardiac bypass, usually combining hypothermia with extracorporeal circulation.[65]

Pacemakers

In the first decades of the twentieth century, with the new electrocardiograph, researchers were studying heart rhythms, notably problems of atrial fibrillation and heart block. As the historian Kirk Jeffrey points out, they could not explain why these problems developed, but they could identify the symptoms in living patients and give an account of the probable course of each disorder over time. The new knowledge of heart rhythms gained from the electrocardiograph, however, did not contribute fresh clinical treatment of rhythm disturbances (arrhythmias) at this time. Physicians continued to treat arrhythmias with drugs.[66]

Pacemakers — machines that send electrical impulses to the heart to stimulate the heart muscle — evolved from large, electrically powered and battery-powered machines that resided outside the body to much smaller, totally implantable devices. One of the earliest external pacemakers was introduced by the American cardiologist Albert S. Hyman (1893–1972). In 1932, he announced his invention of an artificial pacemaker. Hyman intended his machine to restart healthy hearts that had stopped beating. His pacemaker produced a uniform electrical current for six minutes through a needle electrode that the surgeon was to insert between the first and second ribs into the right atrium (top of the heart) of the patient. The machine measured 12 inches long by 12 inches wide by 15 inches high ($30 \times 30 \times 40$ cm) and weighed about 16 pounds (7 kg), including a spring motor and hand crank, all of which fit into a carrying case. It was a stand-alone piece of hardware that was to be used chiefly for emergency resuscitation in the operating room.

Tested on animals in both the United States and Germany, the Hyman pacemaker was never used on human subjects. For starters, technical problems with the machine probably made it unusable. Furthermore, few surgeons would have had the confidence to stab the needle electrode into the small, precise region of the right atrium of their dying patients. There was complete rejection of the Hyman pacemaker by physicians. According to the historian Kirk Jeffrey, there was simply no place in clinical medicine for the pacemaker at that time.[67]

The first clinical external pacemakers emerged twenty years later. In 1952, the Boston cardiologist Paul Zoll (1911–1999) announced that he had successfully kept a patient alive through numerous episodes of cardiac standstill using a bedside device that delivered electrical pulses to the heart.[68] Zoll had developed an external pacemaker, a machine that sat at the side of the bed with a strap to hold two chest electrodes in place on either side of the heart. It was a closed chest treatment meant as an emergency action to revive patients by stimulating contraction of the ventricles (bottom of the heart). A high voltage was necessary to stimulate the heart, and as a result, patients found it too painful for extended use. Despite this, and unlike the Hyman pacemaker, Zoll's external pacemaker gained a place in hospitals. Physicians found the machine easy to set up and to use; results were also easy to interpret. However, although the painful stimuli did keep patients alive and physicians could operate the machine, the external pacemaker had only limited clinical use.[69]

In Canada, the Toronto General Hospital–National Research Council team of cardiac surgeon Wilfred Bigelow (1913–2005), research fellow John Callaghan, and engineer Jack Hopps (1919–1998) built an artificial pacemaker in the course of their research on hypothermia.[70] They encountered problems with cardiac standstill or ventricular fibrillation with their animals as they dropped their temperatures. In 1949–51, they built a laboratory pacemaker consisting of an external pulse generator and a catheter electrode to be inserted in the dog's right atrium via a vein.[71] Their intent was to build a stimulator for use in patients who required cardiac pacing while their bodies rewarmed from induced hypothermia. At this time, they did not plan experiments to study artificial pacing in hearts at normal body temperature. According to Bigelow, the Toronto team shared their research, notably the full details of the electrical circuit system, with Paul Zoll, who then applied it to his machine.

The Toronto team built an artificial pacemaker (1950) and a combined stimulator-defibrillator (1951) that were used during the team's hypothermia research. According to Hopps,

> *The first cardiac pacemaker was built in our NRC [National Research Council] laboratory in early 1950. It was the era of vacuum tubes, long before the development of the transistor so it did not compare in size with the present-day pacer . . . . Our original unit had two controls to vary the voltage and the pulse rate. The first electrodes were designed for separate placing on the surface of the heart. Almost immediately we developed a new system with two ring electrodes mounted near the tip of a hard rubber catheter, for insertion through a vein until the electrodes were in proximity to the S-A node, inside the heart. The electrodes could be*

positioned by X-ray visualization but with a little practice the surgeons became expert in judging the position and the response of the heart gave confirmation when the stimuli became effective.[72]

Smith and Stone Limited, a Canadian company of former radar designers from the wartime years at the National Research Council, built a commercial pacemaker based on the Toronto team's design. According to one source, more than twenty units were delivered to centres in Canada, the United States, and Europe.[73] It is unknown which centres in Canada requested this device, and there is no evidence that this pacemaker was adopted for clinical use in Toronto. As Bigelow himself viewed it, the pacemaker was a spin-off of their hypothermia research and remained in the lab.[74]

During the 1950s, the artificial pacemaker had limited human use until transistor circuitry innovations were introduced. With this new technology, a smaller pacemaker could be built, eventually evolving into a device that was totally implantable under the skin with all wires connecting it to the heart. Earl E. Bakken (b.1924), whose U.S. company Medtronic Inc. would grow to dominate the pacemaker market, developed the first wearable (but external) transistorized pacemakers in the late 1950s. The first successful totally implantable pacemaker operation took place in 1958 at the Karolinska Institute in Stockholm, Sweden, by the researcher Rune Elmqvist (1906–1996) and heart surgeon Ake Senning (1915–2000). By the mid 1970s, lithium batteries allowed even smaller, more sophisticated, longer-lasting pacemakers. Artificial pacemakers have evolved from external "emergency" machines intended to resuscitate patients from heart standstill to implantable devices with "on demand" pacing to provide heart rhythm regulation as necessary.

Figure 44. *Jack Hopps and his co-workers at the National Research Council built this external pacemaker in 1951. It was a combined stimulator-defibrillator, with a foot pedal to trip the single 200-volt defibrillating shock.*
(W. G. Bigelow, *Cold Hearts: The Story of Hypothermia and the Pacemaker in Heart Surgery* [Toronto: McClelland & Stewart, 1984], 108)

Conclusion

Nineteenth- and twentieth-century research and clinical work aimed at understanding, diagnosing, and treating heart disease fostered the introduction of new devices that became essential diagnostic tools for the physician. Developments in physiology and medicine during the nineteenth century set the stage for greater understanding and further treatments of heart failure. It was then that the stethoscope and the sphygmomanometer were created for diagnostic purposes. With the stethoscope the physician listened to heart sounds, which provided information about many heart functions, such as rhythm and the status of valves. The sphygmomanometer was an instrument for measuring blood pressure, helpful in determining the pumping efficiency of the heart, which was more fully developed in the twentieth century. The electrocardiograph provided the physician with a graphic representation of heart function, specifically the electrical activity of the heart, and proved useful in providing information about the physical condition and functioning of the heart muscle. Cardiac catheterization and angiocardiography gave physicians more detailed views of obstructions or damage in the arteries around the heart. By the mid-twentieth century, knowledge of various heart diseases and physicians' ability to diagnose poor heart function and efficiency had increased dramatically. In comparison, their ability to treat heart disease through drugs, surgery, and devices like the pacemaker was only beginning to show promising results.

In studying the medical technology surrounding heart disease, several familiar themes from other disease studies emerge. First, the shift from nineteenth-century medical instrumentation to twentieth-century medical technologies is clear. The stethoscope and sphygmomanometer were instruments that were portable, affordable, and easy to operate, enabling physicians to acquire them for their home offices and use them in home visits. The electrocardiograph and external pacemaker were larger, more expensive

technologies that hospitals, more than physicians, purchased and that became valued diagnostic and therapeutic tools.

Second, the site of diagnosis and treatment, especially for heart disease patients, was shifting from the home and doctor's office to the research laboratory and hospital. The hospital was evolving into the preferred diagnostic centre, and later diagnostic and therapeutic centre, in the health care system. Heart disease investigation and treatment took place in the hospital, where diagnosis was facilitated by the electrocardiograph and angiocardiography, and where new surgical and pacemaker treatments were offered.

Third, cardiac technologies reflected the shift in function for instruments and devices from simply diagnosis to diagnosis and treatment. At mid-century, there were more diagnostic than therapeutic technologies developed for heart disease. But by the end of the twentieth century, artificial heart valves, improved implantable pacemakers, cardiac transplantation, mechanical hearts, and ventricular assist devices were additional therapeutic technologies gaining acceptance.

Fourth, the cardiac technologies explored in this chapter did not alter rising mortality and morbidity statistics relating to heart diseases. Heart disease remained the number one killer; the medical profession simply improved its ability to understand and diagnose heart disease.

Most cardiac technologies were designed as research tools to study and better understand heart function. For example, pulse recorders were used first by researchers to explain the physiology of circulatory disease, and only later by clinicians to identify circulatory anomalies or disease in their patients. Some cardiac technologies were not intended for clinical use. James Mackenzie's work on the polygraph is one such example. His concerns about the clinical use of the polygraph typify the twentieth-century debate at whose core are the questions, is medicine an art or a science? and what relative weight should be given to subjective versus objective measures of diagnosing and treating disease? Non-medical groups such as insurance companies, hospital administrators, and patients have contributed to this debate, and for much of the twentieth century, swung the balance towards objective measures in medicine.

The social context in which technologies are introduced, accepted, rejected, or refined is significant with regard to cardiac technologies. The electrocardiograph, despite emerging as one of the most useful cardiac diagnostic tools, did not have a clinical place in the hospital until years after its introduction to the medical community. Compared to the electrocardiograph, the external pacemaker, despite technical problems and patient discomfort, was adopted by hospitals more quickly, albeit with limited use until transistorized technology became available. What does this say about technology and society at these points in time? It reflects the growing confidence of the medical profession and their patients in medical technology generally and in cardiac technologies specifically. Even as cardiac technologies such as catheterization and angiocardiography became more invasive, patients seemed to accept them; twentieth-century patients, for the most part, demonstrated faith in technology to provide information. In the case of heart disease, ever more sophisticated diagnostic tools, monitoring equipment, and therapeutic procedures would reflect increased optimism in technological solutions in the second half of the twentieth century.

Notes

1. According to the American Heart Association, the leading causes of death for males and females in the United States in 1999 were (1) cardiovascular disease, (2) cancer, (3) accidents, (4) chronic lower respiratory diseases, (5) diabetes, and (6) influenza and pneumonia. Health Canada statistics for the leading causes of death for Canadians in 1994 were not unlike the AHA's findings. For Canadian statistics, see Heart and Stroke Foundation of Canada, *The Changing Face of Heart Disease and Stroke in Canada 2000* (Heart and Stroke Foundation of Canada, 1999), online at www.phac-aspc.gc.ca/ccdpc-cpcmc/cvd-mcv/publications/hdsc_2000_e.html, as well as American Heart Association, *2002 Heart and Stroke Statistical Update* (Dallas, Tex.: American Heart Association, 2001).
2. Heart and Stroke Foundation, Fact Sheet, www.heartandstroke.ca (accessed December 6, 2007).
3. Health Canada, "Economic Burden of Illness in Canada, 1998," www.heartandstroke.ca (accessed December 6, 2007).
4. Roy Porter, *The Greatest Benefit to Mankind: A Medical History of Humanity* (New York: W. W. Norton & Company, 1997), 583.
5. The Framingham Heart Study, based in Framingham, Massachusetts, is a longitudinal cardiovascular study sponsored by the U.S. National Heart, Lung, and Blood Institute that began in 1948. Initially, more than 5,000 adults participated in this study of heart disease and its relationship to diet, physical activity, and other behaviours. The conclusion of the study is that cardiovascular disease is largely the result of measurable and modifiable risk factors. For more on this study see David Levy and Susan Brink, *A Change of Heart: How the People of Framingham, Massachusetts, Helped Unravel the Mysteries of Cardiovascular Disease* (New York: Knopf Books, 2005).
6. See Harold N. Segall, *Pioneers of Cardiology in Canada, 1820–1970: The Genesis of Canadian Cardiology* (Toronto: Hounslow Press, 1988).

7. Porter, *Greatest Benefit to Mankind*, 211–6; Jacalyn Duffin, *History of Medicine: A Scandalously Short Introduction* (Toronto: University of Toronto Press, 1999), 46–8.
8. Arthur Selzer, *Understanding Heart Disease* (Berkeley: University of California Press, 1992), 1–25.
9. Duffin, *History of Medicine*, 196.
10. Audrey Davis, *Medicine and Its Technology: An Introduction to the History of Medical Instrumentation* (Westport, Conn.: Greenwood Press, 1981), 93. See also Jacalyn Duffin, *To See with a Better Eye: A Life of R. T. H. Laennec* (Princeton, N.J.: Princeton University Press, 1998). For the Canadian context, see Harold N. Segall, "Introduction of the Stethoscope and Clinical Auscultation in Canada," *Journal of the History of Medicine and Allied Sciences* 22 (1967): 414–7.
11. The English researcher Stephen Hales published his findings based on this method in 1733. See H. A. Snellen, *History of Cardiology* (Rotterdam: Donker Academic Publications, 1984), 45–8.
12. Davis, *Medicine and Its Technology*, 125.
13. Ibid.
14. Porter, *Greatest Benefit to Mankind*, 343.
15. Davis, *Medicine and Its Technology*, 126.
16. Ibid.
17. The few sources available on early cardiology innovations in Canada are Rénald Lessard, "Les débuts de la cardiologie à Québec," *Canadian Society for the History of Medicine* (Autumn 1982): 1–4; Harold N. Segall, "William Osler and the Genesis of Cardiology in Canada," *Canadian Journal of Cardiology* 2 (1986): 320–3; and Harold N. Segall, "Some Aspects of the Genesis of Cardiology in Canada — The Montreal Factor," *Annals Royal College of Physicians and Surgeons in Canada* 20 (1987): 421–5, 497–502.
18. Merriley Borell, "Training the Senses, Training the Mind," in *Medicine and the Five Senses*, ed. W. F. Bynum and Roy Porter (Cambridge: Cambridge University Press, 1993), 247.
19. Davis, *Medicine and Its Technology*, 208.
20. Ibid.
21. See Audrey B. Davis, "Life Insurance and the Physical Examination: A Chapter in the Rise of American Medical Technology," *Bulletin of the History of Medicine* 55, no. 3 (1981): 392–406.
22. See Davis, "Life Insurance and the Physical Examination." The industry also made alliances with academic research: in 1927, the Metropolitan Life Insurance company funded a clinic in industrial medicine at the Montreal General Hospital. Joseph Hanaway, Richard Cruess, and James Darragh, *McGill Medicine*, vol. 2, *1885–1936* (Montreal: McGill–Queen's University Press, 2006), 193.
23. Davis, *Medicine and Its Technology*, 186.
24. Honorary Advisory Council for Scientific and Industrial Research (Canada), *Report of the Administrative Chairman (1920–1921)*, 21, cited in Georgina D. Feldberg, *Disease and Class: Tuberculosis and the Shaping of Modern North American Society* (New Brunswick, N.J.: Rutgers University Press, 1995), 140.
25. Wendy Mitchinson, *Giving Birth in Canada, 1900–1950* (Toronto: University of Toronto Press, 2002), 25.
26. Davis, *Medicine and Its Technology*, 207.
27. Ibid., 128–31.
28. Harold N. Segall, "Introduction of Electrocardiography in Canada," *Canadian Journal of Cardiology* 3, no. 8 (November/December 1987): 360.
29. Porter, *Greatest Benefit to Mankind*, 582.
30. Davis, *Medicine and Its Technology*, 131.
31. Porter, *Greatest Benefit to Mankind*, 582.
32. For additional description and a diagram, see P. D. Lamson, *The Heart Rhythms* (Williams & Wilkins Co., 1921), 20–2, and M. J. G. Cattermole and A. F. Wolfe, *Horace Darwin's Shop: A History of the Cambridge Scientific Instrument Company, 1878–1968* (Bristol: A. Hilger, 1987), 220–36.
33. This description of Einthoven's electrocardiograph is taken from "Electricity and the Heart: A Historical Perspective," by NASPE (North American Society of Pacing and Electrophysiology). See George E. Burch and Nicholas P. DePasquale, *A History of Electrocardiography* (1964; reprint, San Francisco: Norman Publishing, 1990), 20–55, or the original description at W. Einthoven, "Ein neues Galvanometer," *Annal. Physcik. Folge* 4, no. 12 (1903): 1059. Another useful primary source is Lewellys F. Barker, "Electrocardiography and Phonocardiography: A Collective Review," *Johns Hopkins Hospital Bulletin* 21 (1910): 358–89.
34. Burch and DePasquale, *History of Electrocardiography*, 47–50.
35. Porter, *Greatest Benefit to Mankind*, 582.
36. Duffin, *History of Medicine*, 203.
37. See H. A. Snellen, *Willem Einthoven — Father of Electrocardiography* (Norwell, Mass.: Kluwer Academic Publishers, 1995).
38. Burch and DePasquale, *History of Electrocardiography*, 36.
39. Sir William Osler sent a letter and a donation to the Montreal General Hospital to persuade the administration to purchase an ECG machine. Clyde Partin, "Dropped Beat: Sir Willam Osler's Tenuous Embracement of the Electrocardiograph," *Journal of Electrocardiology* 40 (2007): 236. See also Harold N. Segall, *Pioneers of Cardiology in Canada*.
40. Harold N. Segall, "Canada's First ECG Machine: Shut Down the Laundry Before Use," *CMAJ* 140, no. 11 (June 1989): 1369.
41. Burch and DePasquale, *History of Electrocardiography*; John Burnett, "The Origins of the Electrocardiograph as a Clinical Instrument," *Medical History* suppl. 5 (1985): 53–76; Joel Howell, *Technology in the Hospital: Transforming Patient Care in the Early Twentieth Century* (Baltimore: Johns Hopkins University Press, 1995), 122.
42. Harold N. Segall, "Introduction of Electrocardiography in Canada," 358–61.
43. In 1928, Ernstine and Levine reported the use of vacuum tubes to amplify the electrocardiogram instead of the mechanical amplification of the string galvanometer. See A. C. Ernstine and S. A. Levine, "A Comparison of Records Taken with the Einthoven String Galvanometer and the Amplifier-Type Electrocardiograph," *American Heart Journal* 4 (1928): 725–31.
44. Selzer, *Understanding Heart Disease*, 40–5.
45. Kirk Jeffrey, *Machines in Our Hearts: The Cardiac Pacemaker, the Implantable Defibrillator, and American Health Care* (Baltimore: Johns Hopkins University Press, 2001), 42.
46. Ibid., 42–3.
47. Porter, *Greatest Benefit to Mankind*, 583.
48. See Selzer, *Understanding Heart Disease*, 49–53.
49. This section is taken from Shelley McKellar, *Surgical Limits: The Life of Gordon Murray* (Toronto: University of Toronto Press, 2003), chap. 3, 52–75.
50. These statements by Billroth and Paget are often quoted. See Lael Wertenbaker, *To Mend the Heart* (New York: Viking Press, 1980), 50; Robert G. Richardson, *The Scalpel and the Heart* (New York: Charles Scribner's Sons, 1970), 27–8.

51. Christopher Lawrence, "Moderns and Ancients: The 'New Cardiology' in Britain, 1880–1930," in *The Emergence of Modern Cardiology*, ed. W. F. Bynum, C. Lawrence, and V. Nutton (London: Wellcome Institute for the History of Medicine, 1985), 12, 33, and note 139.
52. Harris B. Shumacker Jr, *The Evolution of Cardiac Surgery* (Bloomington: Indiana University Press, 1992), 107–8; Wertenbaker, *To Mend the Heart*, 69–73.
53. See C. G. Roland, "Maude Abbott and J. B. MacCallum: Canadian Cardiac Pioneers," *Chest* 57 (1970): 3717; H. E. MacDermot, *Maude Abbott: A Memoir* (Toronto: Macmillan Co., 1941).
54. Maude E. Abbott, "Congenital Heart Disease," reprinted from *Nelson Looseleaf Medicine* 4 (1932): 207–321 and found in Helen B. Taussig, *Congenital Malformations of the Heart* (New York: Commonwealth Fund, 1947).
55. Shumacker, *Evolution of Cardiac Surgery*, 66–75.
56. The other well-known "blue baby doctor" in Canada was W. T. Mustard of Toronto's Hospital for Sick Children. Early in his career, Mustard performed orthopedic surgery, pioneering a tendon-transfer procedure that bears his name. As a cardiac surgeon, he performed many blue baby operations (after Murray), improved older operations, and in 1963 developed a difficult new procedure, the Mustard procedure, to repair transposition of the great vessels (a grave heart defect and another blue baby cause). This procedure saved hundreds of blue babies. Mustard is the only Canadian surgeon to have two procedures in different specialties named after him. See Marilyn Dunlop, *Bill Mustard: Surgical Pioneer* (Toronto: Hannah Institute & Dundurn Press, 1989).
57. D. W. G. Murray, Papers, MG 30, B110, Vol. 1, File 1, "Heart Operations Patient List, 1946–51," Library and Archives Canada.
58. "Surgeon Here Wins Acclaim of Continent," *Toronto Evening Telegram* (24 October 1946).
59. John W. Scott, letter to Shelley McKellar, 24 March 1996.
60. For an example of this celebratory reporting, see Roy Greenaway, "U.S. Surgeons Come to See Toronto-Cured Blue Babies," *Toronto Star* (16 September 1946); "Over 200 Blue Babies Saved in Two Years of Operations," *Toronto Evening Telegram* (29 November 1946); "Once Blue, Now Normal," *Sudbury Daily Star* (16 September 1948); June Callwood, "A Day in the Operating Room," *Maclean's Magazine* (15 July 1953): 8–10, 54.
61. Bigelow remembers his colleagues' skepticism, writing: "It was a blasphemy. This concept completely contradicted currently accepted teaching, which was to avoid any fall in body temperature." See Wilfred G. Bigelow, *Cold Hearts: The Story of Hypothermia and the Pacemaker in Heart Surgery* (Toronto: McClelland & Stewart, 1984), 40, 51.
62. See A. Romaine-Davis, *John Gibbon and His Heart-Lung Machine* (Philadelphia: University of Pennsylvania Press, 1991); Harris B. Shumacker Jr, *A Dream of the Heart: The Life of John H. Gibbon, Jr., Father of the Heart-Lung Machine* (Santa Barbara: Fithian Press, 1999).
63. In additional to mechanical oxygenators, biological oxygenators were experimented with. In the early 1950s, W. T. Mustard used a Cowan perfusion pump and a monkey lung as an oxygenator in cardiac bypass operations. There were obvious problems with using animals in this way, notably deterioration of lung function and pulmonary congestion during the operation. See Bigelow, *Cold Hearts*; Dunlop, *Bill Mustard*; Segall, *Pioneers of Cardiology in Canada*, 398–404.
64. Dr W. T. Mustard, Hannah Institute for the History of Medicine Oral History Collection, vol. 33, 73–4, Thomas Fisher Rare Book Library, University of Toronto.
65. In the second half of the twentieth century, as a result of open-heart surgery, various new procedures emerged, including artificial and natural valve replacement, heart transplantation, external and implantable artificial hearts, and ventricular assist devices. For additional information, see Stephen L. Johnson, *The History of Cardiac Surgery, 1896–1955* (Baltimore: Johns Hopkins University Press, 1970); Richardson, *Scalpel and the Heart*; Wertenbaker, *To Mend the Heart*; Shumacker, *Evolution of Cardiac Surgery*.
66. Jeffrey, *Machines in Our Hearts*, 26–7.
67. See Jeffrey, *Machines in Our Hearts*, 28–31, 34; Dennis Stillings, *The Early History of Attempts at Electrical Control of the Heart: Harvey to Hyman* (Minneapolis: Medtronic, Inc., 1979); Wilson Greatbatch, *The Making of the Pacemaker: Celebrating a Life-Saving Invention* (Amherst, N.Y.: Prometheus Books, 2001); Patrik Hidefjäll, *The Pace of Innovation: Patterns of Innovation in the Cardiac Pacemaker Industry* (Linköping, Sweden: Linköping University, 1997).
68. This case is reported in P. M. Zoll, "Resuscitation of the Heart in Ventricular Standstill by External Electrical Stimulation," *New England Journal of Medicine* 247 (1952): 768.
69. Jeffrey, *Machines in Our Hearts*, 56.
70. Personal papers of Wilfred G. Bigelow and John Alexander Hopps are both available for researchers. Bigelow's papers are held at the University Health Network Archives in Toronto as the W. G. Bigelow Personal Papers. Hopps's papers are held at Library and Archives Canada in Ottawa as the John Alexander Hopps fonds, MG 31-J31.
71. The Toronto team's research on the artificial pacemaker was first presented in J. C. Callaghan and W. G. Bigelow, "An Electrical Artificial Pacemaker for Standstill of the Heart," *Annals of Surgery* 134, no. 1 (July 1951): 8–17. See also Segall, *Pioneers of Cardiology in Canada*, 399–404, 430–2.
72. John A. Hopps, *Passing Pulses: The Pacemaker and Medical Engineering: A Canadian Story* (Gloucester, 1995), 37.
73. John A. Hopps, "The Development of the Pacemaker," *Pacing and Clinical Electrophysiology* 4, no. 1 (January–February 1981): 108.
74. See Bigelow, *Cold Hearts*, chap. 4, "The Pacemaker: A Hypothermia Spin-Off," 88–109.

CONCLUSION
Change and Continuity: Medicine and Medical Technology at 1950

The child born in 1950 could expect a longer life than his or her Canadian ancestor born in 1900. Infant and child mortality rates had declined dramatically. The improvements came not only because sulpha drugs and penicillin could fight infectious diseases, but more importantly, because the pasteurization of milk, chlorination of drinking water, and immunization could prevent them. Although the country's peak year for active cases of tuberculosis was 1953, that scourge, and polio, would within ten years join diphtheria as controllable, even preventable, diseases. Some afflictions were on their way to being eradicated in Canada, such as smallpox, syphilis, rheumatic fever, and vitamin-deficiency diseases. Diabetes and other diseases caused by hormone imbalance could now be treated and lives were saved.

If the discovery of antibiotics dominates the therapeutics narrative in the first half of the century, the explosion of synthetic drugs is a central development of the postwar years. Effective analgesics, anti-inflammatories, antihistamines, diuretics, and so on changed the experience of illness for millions. By the British physician and science writer James Le Fanu's count, the number of useful drugs rose from about a dozen in 1930 to more than 2,000 in 1960.[1] Starting with the sulpha drugs that were developed in the 1930s, many of the chemical drugs were products of scientific method combined with accident, but were not driven by scientific theory. In Le Fanu's words, "The therapeutic revolution of the post-war years was not ignited by a major scientific insight, rather the reverse: it was the realization by doctors and scientists that it was not necessary to understand in any detail what was wrong, but that synthetic chemistry blindly and randomly would deliver the remedies that had eluded doctors for centuries."[2] One such potent and serendipitous addition to *materia medica* was chlorpromazine, the first drug that mitigated the dreadful affects of schizophrenia. It was first tested in North America in Montreal in 1954. The efficacy of chlorpromazine demonstrated that mental illness was a biological affliction, a problem of brain chemistry. The drug spurred a reorientation to mental illness as a physical rather than social or emotional disorder.

Partly as a result of some of these achievements, the middle of the twentieth century marked what several historians have called a paradigm shift in medicine.[3] The bacteriological paradigm — which had directed the focus of medical attention on germs and infectious diseases for decades — faded dramatically with the advent of anti-tubercular drugs. Western medical research and clinical attention turned to non-infectious diseases, especially heart disease and cancer, both of which were becoming leading causes of death. James Le Fanu names 1950 as a watershed for another reason: that year U.S. researchers offered proof that smoking caused cancer.[4] In his opinion, this marked the decisive shift in medical authority from clinical knowledge, "the cumulative wisdom acquired through everyday practice," to statistical knowledge.[5] The 1950s were the beginning of randomized clinical trials and other aspects of what would become evidence-based medicine. This new technology — knowledge and practices — was changing the structure of medicine, and the relative prestige of its specialties, as had the development of laboratory science and early diagnostic tools fifty years before.

The child born in 1950 would probably come into contact with many more machines and devices than his or her predecessors, and that experience would be gained away from home, beginning with birth. Before the First World War, patients became familiar with new technology first at the bedside and in the doctor's office, and later in the hospital, and understood that the laboratory was a source of diagnoses and prognoses. As the technology and machines grew in complexity, size, and cost, the hospital became the doctor's workshop for diagnosing and treating sick patients. As stated by Jacalyn Duffin: "By mid-century, the hospital had become a place for scientific investigation and cure, furnished with expensive equipment and essential to rich and poor alike. The very sick needed the life support that could be provided only there. Those who were not sick at all entered the hospital for diagnosis, which also depended on machinery."[6]

Doctors' ability to see inside the body was revolutionized because of war technology, including ultrasound. Diagnostic imaging would continue to be the site of dramatic developments in the three decades following the Second World War. In the 1960s, the first CT (computed tomographic) scanner combined X-ray and computer technology. Magnetic resonance imaging

(MRI) was first attempted in the 1970s; it would become a versatile tool for diagnosis of diseases and conditions in most tissues and for examining the flow of blood. Each improvement in imaging brought new possibilities for intervention. While the potential of medical technology suggested improved treatment, even cure, Jacalyn Duffin proposes that its study may "reveal how each invention created new diseases where none had been conceived. And it will uncover more fascinating discrepancies between the aspirations of inventors and the applications that their instruments subsequently find."[7]

Technological innovations in medicine continued to offer what would have been unimaginable to doctors and patients at the beginning of the century. The Zeiss operating microscope, invented in the 1950s, transformed surgery and expanded the possibilities of neurosurgery and transplantation in the 1960s. Lasers also arrived in the 1960s, and were quickly taken up by ophthalmologists and later by other surgeons. Medicine tries to replace what it cannot repair (while still searching for cures), and researchers worked closely with engineers after the Second World War on artificial parts. The Canadians Wilfred Bigelow and Gordon Murray are justly famous for their attempts, successful and not, to repair or replicate heart and kidney function. One of the most famous medical technological developments of the twentieth century was the invention of the artificial heart. Willem Kolff, inventor of the artificial kidney, led an ambitious research program on artificial organs in the United States, and in 1982, the Jarvik-7 artificial heart, a device designed in his laboratory, became the first mechanical heart implanted in a patient as a permanent therapy.[8] Less spectacular, but appreciated by hundreds of thousands, was the development of small hearing aids made possible by the invention of the transistor in 1948.[9] In the 1950s, early attempts at cochlear implants, viewed as a fundamental advance over conventional hearing aids, promised to cure deafness.[10] In Canada, the National Research Council, an important funder of research on TB and war medicine, used new materials and approaches to design technology for the disabled. The resulting devices included an improved white cane and an ultrasonic obstacle detector for the visually impaired. During the 1950s, the NRC researcher George Klein developed the first practical motorized wheelchair for disabled Second World War veterans.[11] Replacement of arthritic hips with plastic and metal joints began in 1962 in England.[12]

Against cancer, X-rays, endoscopes, microscopes, and laboratory blood and tissue tests had invigorated diagnosis and therapeutics before the Second World War. The keynote of the postwar decade was even bolder intervention. Increasingly aggressive surgery was encouraged by antibiotics, anaesthetic advances, and blood transfusion, and, as after the First World War, by the confidence and enhanced skills of surgeons returning from battlefield operations. However, according to Barron Lerner, the main cause was larger: "Such operations gained popularity because they fit with a cultural climate that saw increasingly aggressive invasion of the body as an appropriate way to counteract disease."[13] Radiation treatment also became more powerful, refined, and utilized. In 1951, Canada became a leader in the development of more effective radiation therapy in the form of the powerful cobalt 60 "bomb" or radiation machine built by Harold Johns. Johns used the cobalt-60 isotope produced at Chalk River, a product of National Research Council nuclear activities.[14] As in the United States, the Canadian government moved further into medical research as one outgrowth of the larger role it had taken on during the war years.

However, a new era, less enthusiastic about scientific medicine and its technological orientation, was soon to begin. Cancer was neither cured nor, in many cases, made more bearable for those it afflicted. The year 1950 was a low point in popular and medical interest in alternative medicine. However, by the 1970s, critics were looking once more at mainstream medicine with a jaundiced eye. In the pharmaceutical industry, great hopes for more "magic bullets" had given way to disappointment, even public anger, over the failure of medical technology and its professional and government watchdogs to protect patients from iatrogenic, or doctor-caused, illness. The most spectacular and publicized disaster in Europe was thalidomide, a drug prescribed for nausea in pregnancy, which caused severe non-reversible birth defects in thousands of babies in the late 1950s.[15] As important in the longer term, the overuse of antibiotics fed the rise of antibiotic-resistant "super bugs," including a form of multi-drug-resistant tuberculosis.

Patients as a group were absorbing the new ideals of the 1960s "counterculture." The larger value placed on the individual meant that patients resented being treated as statistics, as identical components of a group whose only characteristic was a given disease. By the 1970s, the new social history of medicine engendered ambivalent theoretical perspectives on technology; technology was seen as a tool that worsened class, gender, and ethnic barriers and inequalities, and also promoted the power of doctors at the expense of patients. For instance, Stanley Reiser argues that technology separated, physically and emotionally, the doctor and the patient, a process that had begun early in the twentieth century.[16] Joel Howell comments on how the adoption of blood tests, urinalysis, and X-rays has resulted in less time spent by physicians with their patients.[17] Doctors as well as patients became dis-

satisfied by the deterioration of the doctor-patient relationship.

The escalating cost of medicine and technology began to disturb governments whose citizens expected the best in health care. Beginning in the 1920s, but escalating in the 1950s, medical technology became bigger business than ever. The many small X-ray manufacturers of the period between the world wars had gone, for the new technology was expensive to develop and to manufacture. The increase in scale also applied to pharmaceutical industries and research facilities. Official dismay over climbing expenses was joined by popular distrust about the utility and safety of technology; these reactions erupted in the late 1970s around the introduction of the CT scanner. One result was an explosion in the popularity and range of alternative medicine, from acupuncture to homeopathy to therapeutic touch. Canadians joined this Anglo-European questioning of mainstream medicine and welcoming of alternative, later "complementary" medicine.

The preceding chapters provide a selective review of medicine and medical technology from 1900 to 1950, sketching international developments that were adopted and adapted in Canada. They also highlight some Canadian contributions to the development of medical technology in the first half of the century. A number of themes recur in these chapters: the changing site of health care and professional knowledge; the shift from nineteenth-century medical instruments and clinical "arts" to the twentieth-century "science" of medical machines, procedures, and equipment; the expanding function of technology from diagnostic tools to also therapeutic devices; the changing doctor-patient relationship as a result of technological mediation; the impact of government funding of medical research in wartime; the growing optimism in technological solutions and the emergence of the technological imperative in medicine.

In this study, two significant patterns from Canadian achievements in medicine and medical technology emerge — the centrality of the university in medical research, and the vigour of public health initiatives in this country. The discovery of insulin remains our most famous achievement, a product of team brilliance and university institutional not-for-profit support. In the Western world's fight against tuberculosis, individual Canadians and governmental responses made Canada a leader, instituting mass surveys, helping to develop the BCG vaccine, and enhancing mobile fluoroscopy. As these concluding remarks indicate, there is great change but there are also intriguing continuities in the history of medical technology in the decades following 1950, and in Canada's participation in those developments.

Notes

1. James Le Fanu, *The Rise and Fall of Modern Medicine* (London: Little, Brown, & Co., 1999), 206.
2. Ibid., 210. See also Jacalyn Duffin, "Poisoning the Spindle: Serendipity and Discovery of the Anti-Tumor Properties of the Vinca Alkaloids," *CBMH* 17 (November 2000): 157–9.
3. See also Barbara Clow, *Negotiating Disease: Power and Cancer Care, 1900–1950* (Montreal: McGill–Queen's University Press, 2001); Paul Starr, *The Transformation of Modern Medicine* (New York: Basic Books, 1984).
4. Le Fanu, *Modern Medicine*.
5. Ibid., 29–30.
6. Jacalyn Duffin, *History of Medicine: A Scandalously Short Introduction* (Toronto: University of Toronto Press, 1999), 206.
7. Ibid., 208.
8. In December 1982, Barney Clark, a 61-year-old dentist from Seattle, Washington, became the celebrated first patient to undergo the experimental procedure, living 112 days with the Jarvik-7 artificial heart. See Shelley McKellar, "Artificial Hearts: A Technological Fix More Monstrous Than Miraculous?" in *The Technological Fix: How People Use Technology to Create and Solve Problems*, ed. Lisa Rosner (New York: Routledge Press, 2004), 13–29; Shelley McKellar, "Limitations Exposed: Willem J. Kolff and his Contentious Pursuit of a Mechanical Heart," in *Essays in Honour of Michael Bliss: Figuring the Social*, ed. Elsbeth Heaman, Alison Li, and Shelley McKellar (Toronto: University of Toronto Press, 2008), 400–34. For more on the media frenzy surrounding the Barney Clark case, see Barron H. Lerner, *When Illness Goes Public: Celebrity Patients and How We Look at Medicine* (Baltimore: Johns Hopkins University Press, 2006), 180–200.
9. Electric or carbon hearing aids used 3-volt or 6-volt batteries, and became wearable devices about 1902. Next, electronic or vacuum tube aids, which required two batteries, appeared in 1921 but did not appear in a wearable version until 1934. Much smaller transistor hearing aids, requiring only one battery, replaced vacuum tube aids by the early 1950s. Digital hearing aids using digital signal processing (DSP) chips became available in 1982. This information is taken from the Kenneth W. Berger Hearing Aid Museum and Archives at Kent State University, http://dept.kent.edu/hearingaidmuseum (accessed December 23, 2007). For more detailed history on hearing aids, see Ruth Bender, *Conquest of Deafness: A History of the Long Struggle to Make Possible Normal Living to Those Handicapped by Lack of Normal Hearing* (Cleveland: Press of Western Reserve University, 1960), 171–81.
10. The deaf community rejects the medical model of deafness as a medical condition to be cured, and as a result there is debate between the deaf community and the hearing community concerning the role (even need) of cochlear implants. See R. A. R. Edwards, "Sound and Fury; or, Much Ado About Nothing? Cochlear Implants in Historical Perspective," *Journal of American History* 92, no. 3 (2005): 892–920; T. A. Heppenheimer, "Beyond the Hearing Aid," *American Heritage of Invention and Technology* 17, no. 2 (2001): 36–42; Stuart Blume, "Cochlear Implantation: Establishing Clinical Feasibility, 1957–1982," in *Sources of Medical Technology: Medical Innovation at the Crossroads*, ed. N. Rosenberg,

A. C. Gelijns, and H. Dawkins (Washington, D.C.: National Academy Press, 1995), 97–124.

11. See the NRC Scientists and Innovations webpage at www.nrc-cnrc.gc.ca/eng/education/innovations/discoveries/disabled.html.
12. See Julie Anderson, Francis Neary, and John V. Pickstone, *Surgeons, Manufacturers and Patients: A Transatlantic History of Total Hip Replacement* (New York: Palgrave Macmillan, 2007).
13. Barron Lerner, *The Breast Cancer Wars: Hope, Fear, and the Pursuit of a Cure in Twentieth Century America* (New York: Oxford University Press, 2001), 70–1, 74–5.
14. Paul Litt, "Photon Finish: The Race to Build the Bomb," *Beaver* 82, no. 2 (April–May 2002): 28–32.
15. See Insight team of the *Sunday Times* of London, *Suffer the Children: The Story of Thalidomide* (New York: Viking Press, 1979). For the Canadian context, see Barbara Clow, " 'An Illness of Nine Months' Duration': Pregnancy and Thalidomide Use in Canada and the United States," in *Women, Health and Nation*, ed. Georgina Feldberg, Molly Ladd-Taylor, Alison Li, and Kathryn McPherson (Montreal: McGill–Queen's University Press, 2003), 45–66; Barbara Clow, "Defining Disability, Limiting Liability: The Care of Thalidomide Victims in Canada," in *Essays in Honour of Michael Bliss*, ed. Heaman, Li, and McKellar, 304–14.
16. Stanley Reiser, *Medicine and the Reign of Technology* (New York: Cambridge University Press, 1978).
17. Joel Howell, *Technology in the Hospital: Transforming Patient Care in the Early Twentieth Century* (Baltimore: Johns Hopkins University Press, 1995).

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