THE ENGINEERING ENVIRONMENT

PHYTOTRONS *and the* QUEST *for* CLIMATE CONTROL *in the* COLD WAR

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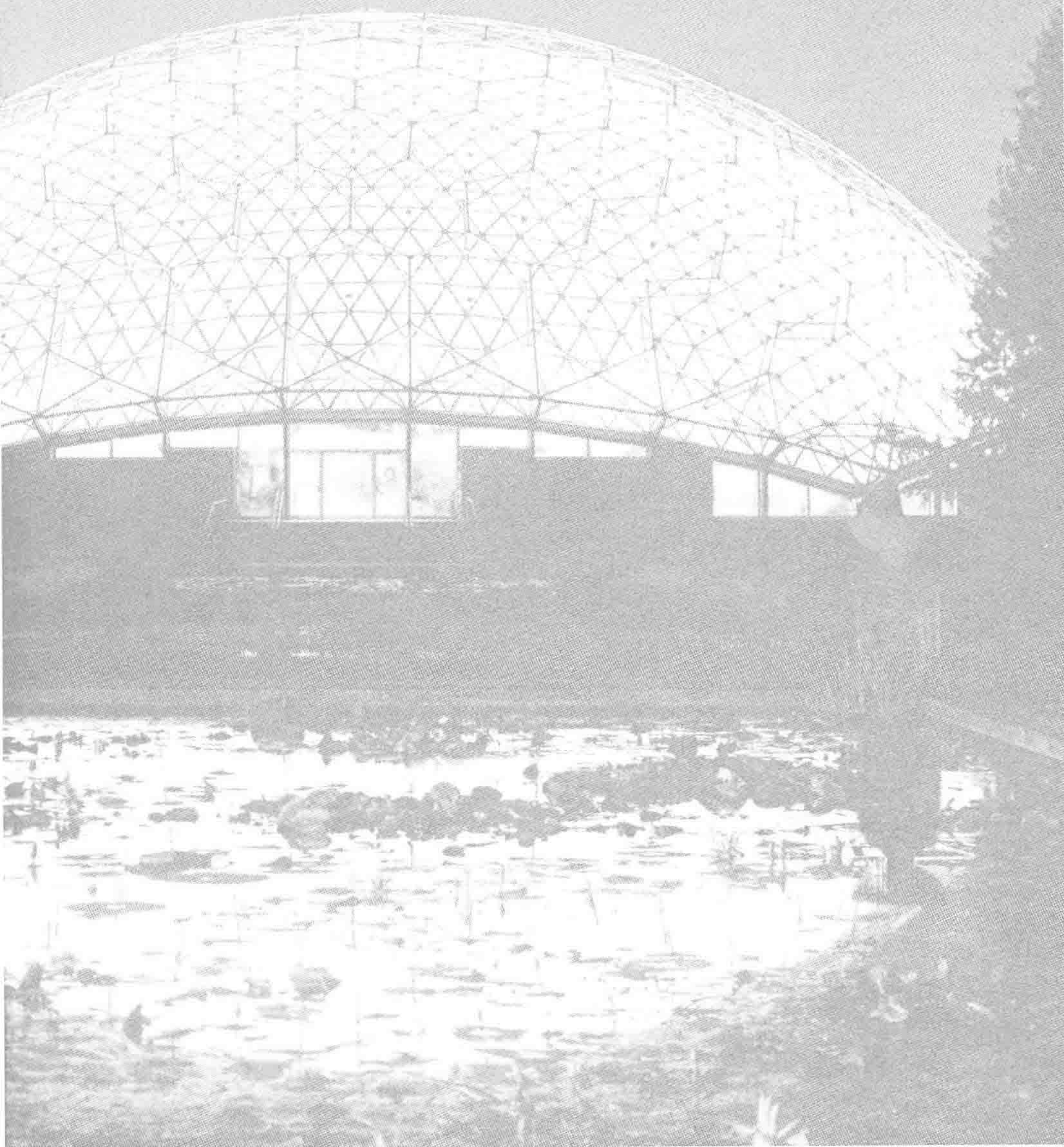

The following website was created to offer a richer overview of the various permutations of trons in modern history. For a chronological diagram of the history of trons, or to post references or materials to other tron projects, please visit:

www.worldoftrons.com

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Jacket art: Climatron exterior at night, as reflected in tropical lilly pools. © Missouri Botanical Garden Archives, http://www.mobot.org
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Engineering the Environment

"Ass!" said the Director. "Hasn't it occurred to you that an Epsilon embryo must have an Epsilon environment as well as an Epsilon heredity?"

— Aldous Huxley, *Brave New World*

Smith is not a man. He is an intelligent creature with the genes and ancestry of a man, but he is not a man. . . . He's been brought up by a race which has nothing in common with us. . . . He's a man by ancestry, a Martian by environment.

— Robert A. Heinlein, *Stranger in a Strange Land*

Observe her, comrades! This is a Bene Gesserit Reverend Mother, patient in a patient cause. She could wait with her sisters ninety generations for the proper combination of genes and environment to produce the one person their schemes required.

— Frank Herbert, *Dune*

ACKNOWLEDGMENTS

On Regent Street in London is the latest form of ecotourism, The National Geographic Store. Deftly combining high-quality materials with local manufacturing and a global vision through human and natural photojournalism, the store is abuzz. I needed a coat for New York. The National Geographic Store has an extensive selection of all degrees of winter coats, both fashionable and able to ward off varying types of arctic winter. The real test of a National Geographic coat, however, comes through identifying precisely what extremes of temperature and wind you are going to encounter and matching them with your jacket. In order to properly make that assessment, the National Geographic Store has installed a climate-controlled room. Three sides are Perspex, which allows all the other consumers to consume the spectacle of the person being subjected to well-below-freezing temperatures and windchills, while the fourth wall supports the refrigeration unit, a wind tunnel, and the infrared sensors that measure the temperature differential all over your body's surface. Dressed in your coat, you can judge how it performs, how comfortable you are, and whether you need to ratchet up a notch in order to defend your body's core temperature against the elements out in the wide world. In a very real sense you are participating in your own controlled-environment experiment.

I had known about the strange controlled-environment laboratories for biology called *phytotrons* for a number of years, but my time in London invigorated my search for them in a variety of ways. Imperial College's academic community of scholars, graduate students, and especially earnest master's candidates once more fueled intellectual fires. Moreover, I finally had time to finish the manuscript on my history of the radio astronomy community, published as *A Single Sky: How an International Community Forged the Science of Radio Astronomy* (MIT Press, 2013). I also turned to publishing the long-delayed case of the Australian phytotron. The central issue for the new radio astronomers was in decid-

ing whether their new science was really an "astronomy" or a "physics" or perhaps both, and what that said for the nature of science neatly divided into discrete disciplines. The creation of phytotrons, coincidentally at the same immediate postwar moment, saw botanists and plant physiologists confront the same problem. The consistent staggering claim was that phytotrons were the cyclotrons of biology. Even more intriguing was a claim from the well-known British cotton breeder S. C. Harland in the *New Scientist* in 1958: "The phytotron is to botany and agriculture what the radio telescope is to astronomy."[1] The radio telescope gave the astronomers a new vision that has uncovered an incredible universe that we can only listen to. Likewise, the phytotron offered a new vision of life and of biology as the study of life.

The story of phytotrons says that the study of biology became an exercise in technological control after the Second World War. This book describes how groups of technologist biologists understood that their new facilities called *phytotrons* effectively made the plant sciences analogous to the physical sciences through control over the physical environment and pursuit of basic science. In so doing they specified what the "environment" meant in the life sciences, a definition that by the end of the century had largely been erased by another new science of the twentieth century, namely, genetics and molecular biology. In part, the history of phytotrons is especially valuable not only because it is largely absent from the history of science but also because it complements the well-studied story of the discovery of the gene. While a biology of the molecular has successfully confronted the scourge of cancer and other diseases that terrify so many, a biology of the environment can contribute toward the threat of climate change that threatens everyone. My hope is that by bringing to light a forgotten part of modern biology, the now recent incarnation of phytotrons, called *Ecotrons*, can establish a biological science of climate change through the experimental study of the whole and not just the parts.

All that began in London where I had the great fortune to meet Hannah Gay, who had just completed her monumental history of Imperial College and who told me of their "Ecotron." I now had a beginning and an end—the first phytotron in Caltech and the Ecotron at Imperial College. In the middle went the various cases the chapter titles outline. I knew about most and needed to research and visit them all. A survey of the

notes will show that the various personal papers of the phytotronists examined during that period have been crucial, as well as the institutional settings that have helped preserve the records even while memories fade. Deserving special mention though is the kind donation of Frits Went's papers to the Missouri Botanical Garden archives by his son, who invaluably saved the lifework of one of the most significant plant scientists of the twentieth century and the founder of phytotrons.

On moving to John Jay College of the City University of New York, I was generously given the opportunity to take a sabbatical term and plow through the research in Australia, California, Saint Louis, Madison, Paris, London, Philadelphia, and Cambridge. For that invaluable opportunity I thank my chair, Allison Kavey, and our provost, Jane Bowers. Among the visits were opportunities to view the continuing work of controlled-growth chambers: my thanks to Jim Klug for a wonderful tour of the growth chambers at Michigan State, and Peter Volk for sharing some grand memories. My appreciation too to William and Melissa Laing in New Zealand for their wonderful and thoughtful correspondence and to the previews of their documentary on the New Zealand Climate Laboratory. Over the years I have been variously and generously supported in my efforts to recover the people of the phytotron: historians, like armies, march on their stomachs.

My appreciation goes to the Maurice Biot Fund supporting archival research at the California Institute of Technology. An early grant from the Rockefeller Archives Center, North Tarrytown, New York, formed an important foundation for my research. I thank the Friends of the University of Wisconsin-Madison Library for their grant to visit the Biotron papers, especially Tom Garver for his friendly welcome. This work was also supported in part by a grant from the City University of New York PSC-CUNY Research Award Program, as well as a grant from the Office for the Advancement of Research at John Jay College.

Parts of this book have previously appeared in "The Phytotronist and the Phenotype: Plant Physiology, Big Science, and a Cold War Biology of the Whole Plant," *Studies in the History and Philosophy of Biological and Biomedical Sciences Part C* 50 (2015), 29–40; "'The Awe in Which Biologists Hold Physicists': Frits Went's First Phytotron at Caltech, and an Experimental Definition of the Biological Environment," *History and Philosophy of the Life Sciences* 36, no. 2 (2014), 209–31; and "Controlling the Environment: The Australian Phytotron and Postcolonial Science," *British Scholar* 2, no. 2 (2010), 197–226. I thank the publishers for permission to reproduce them. Likewise, I thank the many institutions that permitted me to reproduce the wonderful illustrations that help make this story.

Few projects can succeed without the detailed knowledge and diligence of the librarians and archivists on whom the historian is grateful to rely. To get inside multiple controlled environments, I would like to thank the Caltech Archives staff, Shelly Irwin, Mariella Sopano Pelligrino, and Loma Karklins for a wonderful time in Southern California; Andrew Colligan at the Missouri Botanical Garden archives and library; Rosanne Walker at the Adolph Basser library of the Australian Academy of Science; Thomas Harkins at the Duke University Archives; Lajos Bordas of the Dentistry Library at Sydney University; David Null at the University of Wisconsin-Madison archives; Stephen Simon at the LeEster T. Mertz library at the New York Botanical Garden; Karen Stewart at the Desert Research Institute; Isabelle Dujonc au Dépôt des archives du CNRS (Gif-sur-Yvette), and Etienne Wintenberger au Dépôt des archives du CNRS (Paris). Likewise, I have had the able assistance of two students over the years who have sped the process along with their research skills: my thanks go to Lucas Riley and Anjelica Camacho. Furthermore, I thank the legions of unnamed secretaries, typists, and file clerks of the Cold War era for the bountiful copies of immediately legible resources through which the past comes alive.

Then there is the long labor of turning a morass of paper, quotes, diagrams, recording, inscriptions, and other assorted stuff into a work that explains who some people thought they were when they lived. Only through the patient exhumation of others' understandings can we achieve the most significant work of the historian, knowing ourselves through knowing others; history is not written for the past (they're all dead, my old social history professor said) but for the present. For helping me realize that ambition, I owe a deep debt to Andrew Warwick, who took a young man and told him of the world. Likewise, my profound thanks to Allison Kavey for her support and guidance—borrowing that pencil all those years ago was the best move I ever made. Lord Robert Winston of Imperial College, London, was the source of many excellent conversations and an inspirational enthusiast of science and science studies. Likewise, Graham Hollister-Short's conversations about technology just kept on thrilling. As the project developed, Kärin Nickelsen heroically read the entire manuscript and her direct Germanic comments recast several chapters in new and richer ways. Angela Creager's valuable reading of an initial chapter has also meant that many subsequent pages benefited from her project-shaping comments. Stalwartly, Bruce Hunt, Luis Campos, Colin Milburn, Jim Endersby, Catherine Jackson, Karen Rader, Nicolas Rasmussen, Susan Lindee, Betty Smocovitis, Rachel Ankeny, Gail and Mark Schmitt (and the fidotrons), Matt Wisnioski, Frank Bongiorno, Abigail Woods, Serafina Cuomo, Greg Raddick, Christian Joas, Lucie Gerber, Peter Redfield, Caterina Schürch, Bruno Strasser, Helen Anne Curry, and Sharon Kingsland have all listened patiently to my various ravings about trons and gently prodded me back in better directions. Jim Collins gave a splendid commentary on an early paper, while Kim Kleinman lent me early aid with materials about the Climatron. I remain tremendously grateful to the extensive, insightful, and often painfully true comments of my anonymous reviewers. They performed a Herculean task of commenting and editing, and this book would only be a shadow without them. Likewise, to Abby Collier and Alex Wolfe at the University of Pittsburgh Press, who took on this unwieldy project and shaped it into something worthwhile.

There are also the silent partners in one's work without whom little would taste as sweet: Diane Kagoyire, J. J. Shirley, Walter Fralix, the "Yes" Appersons, the Wisnioskis, the Windeyers, the Borises, the Griffins, the Worrells, the DeLeons, the Hungarians, A. J. Benitez and Brad Oister, Kenneth Moore and Derek Bishop, Eric Kolb, Scott Knowles, Dara Byrne, Vivian Ewalefo, and Ezine Okpo, all helped in more ways than they know. Joseph DeLeon quite simply completes my world. Thanks to my parents, Peter G. and Susan Munns, and to Lillian, Max, Trudi, and David MacKay for their patience with their son/brother/uncle's continuing wanderings.

Finally, to Paris, where life becomes art.

ABBREVIATIONS

The Cold War era is almost known by its myriad acronyms. Wherever possible, I have kept their usage to a minimum, but an inevitable list is necessary.

AA	Australian Archives
AAS	Australian Academy of Science
AEC	Atomic Energy Commission (United States)
ASPP	American Society of Plant Physiologists
BSA	Botanical Society of America
CIEP	Committee on International Exchange of Persons (United States)
CIT	California Institute of Technology (Archives)
CNRS	Centre National de la Recherche Scientifique (France)
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
CSR	Commonwealth (Colonial) Sugar Refining
DSIR	Department of Scientific and Industrial Research (Britain)
MBG	Missouri Botanical Garden
MSU	Michigan State University
NAA	National Archives of Australia
NAS	National Academy of Sciences (United States)
NASA	National Aeronautics and Space Administration
NCSU	North Carolina State University
NIH	National Institutes of Health (United States)
NLA	National Library of Australia
NSF	National Science Foundation (United States)
ONR	Office of Naval Research (United States)
RAC	Rockefeller Archives Center Tarrytown, New York
USDA	United States Department of Agriculture

PRELUDE

THE WORLD OF TRONS

Tron. What have you become?
—TRON: Legacy

THIS BOOK concerns the rise and importance of a *tron* in the life sciences, the evocatively named *phytotron*. Phytotrons were, and still are, computer-controlled environmental laboratories consisting of any number of rooms or smaller cabinets, all able to produce any set of climatic conditions. Because the growth and development of any organism depends on its genes and its environment, plant scientists required the ability to create reproducible climates in order to conduct experiments that tested plants' (and some animals') responses to various environmental conditions. Moreover, as we shall see, phytotrons were only the first of an entire family of *trons* for biology. Following the first phytotron came the Climatron, Biotron, and Ecotron, all increasingly elaborate facilities to control climate. There were also a number of smaller associated biological technologies like the assimitron, which measured the CO_2 uptake of a canopy, the dasotron, which studied small ecologies, and the rhizotron, which is a viewing chamber where one can view tree roots and various arthropods that live underground.[1]

Our modern world of science and technology sees trons everywhere. According to the *Oxford English Dictionary* (*OED*), *tron* derives from "a weighing machine," or "the place where the tron was set up." One can still visit Trongate in Glasgow and the Tron Kirk in Edinburgh. In the past century, trons became a ubiquitous part of people's new modern lives, initially through radio: the first real vacuum tubes, Irving Langmuir's "kenotron" and "pliotron" date from around 1915. The name of the kenotron was explicitly drawn from the Greek roots of *keno* for "empty" and *tron* for "tool." Subsequently, the klystron and the rhumbatron became vital components of the radio industry in the 1930s. Trons helped win the Second World War. Heralded as the most important invention of the war, the resonant cavity magnetron—no, not the atomic bomb—developed at the University of Manchester was the heart of every radar set. Later, Radiation Laboratory engineers at the Massachusetts Institute of Technology (MIT) designed the hydrogen thyrotron modulator for Project Cindy—the name of a high-resolution radar set (at about 1 cm) for smaller ships, like PT-boats, for ship search work.[2] In short, trons starred in the Battle of Britain and the war in the Pacific, and assisted in the rescue of a young JFK.

Postwar, a creation of the 1930s, the cyclotron, a particle accelerator and one of the most famous instruments in the history of science, begat another tron lineage that grew to dominate nuclear physics. As cyclotrons proliferated, newer and larger accelerators like the synchrotron and then the Cosmotron (with its twenty-four ignitron rectifiers[3]), Bevatron, and Tevatron offered Cold War era physicists the possibility of creating new elements and peering inside the atom. Moreover, as much in the physical as in the life sciences, trons were not just devices, they were an entire class of cultural objects. It was not just a particle accelerator, it was a Cosmotron! And, as this book describes, it was not just a plant research laboratory, it was a phytotron!

To understand the phytotron and the worldview of those living in the Cold War era, I follow the suffix *-tron*. I take up Robert Proctor's challenge to grapple with the "pragmatics of language," though with technological and scientific instruments and facilities rather than disciplinary regimes. A suffix like *-tron* is, in Proctor's terms, an "embodied symbol."[4] When scientists built and then named their new device a *tron*, whether it was a cyclotron or a phytotron, they inscribed a set of meanings for the world to see, much as ancient knights displayed heraldic shields. The history of any one of those biological and physical instruments is important in its own right, but following the lineages of the trons of physics or biology offers insights, as we shall see, into how scientists, governments, industries, and the public understood that strange period of peace lined by