To begin, I would like to thank my committee, Kat Shea, Maciej Boni, Stephen Berg, and Matt Ferrari, for their support, patience, and guidance throughout my PhD. I am so very grateful to have had the opportunity to work and discuss science with you all; my work is immeasurably better as a result. In particular, I would like to pay particular tribute to Matt. Not only have you helped guide me through all academic puzzles an aspiring researcher could ask for, facilitated numerous collaboration opportunities, and been tireless in helping me become a better scientist, but you are one of the few that pair it with a deep-seated kindness and humanity. I can truly say that the last four years would not have been as productive or joyous without your care and understanding; always providing time and support when I needed it.

I would like to thank the many excellent scientists I had the good fortune of collaborating with. Catherine Herzog, Vivek Kapur, Andrew Read, Rachel Smith, Sreenidhi Srinivasan, and the rest of the Data4Action group for their assistance and comments throughout the first two chapters of this dissertation. Birgit Nikolay, Thomas Roederer, Etienne Gignoux, Catherine Eisenhauer, and Klaudia Porten at Médecins Sans Frontières for providing mentorship during a wonderful few weeks in Paris, and the many months that followed. Amy Winter, Bill Moss, Bryan Patenaude, and Alex Kong for irreplaceable feedback in the development of the outbreak detection project.

I am also incredibly grateful to the whole of the Ferrari lab: Deepit Bhatia, Ariel Greiner, Brian Lambert, Tiffany Leung, Candace Todd, Kai Zou, and honorary member, Emily Howerton. Thank you for acting as a sounding board and providing feedback; my work is notably better for your engagement and strength to listen to me repeat the same presentation multiple meetings in a row.

To the friends throughout my time: John, Suzana, Alexa, Kate, Des, Deepit, Emily, Chiara, Alex, Jared, Ryan, Scott, Betty, Dave, Jen. Thank you for joining me on various outdoor excursions, or just grabbing a coffee or something to eat, and helping make both State College and Toronto wonderful places to live for the past 4 years.

And last, but certainly not least, I would like to thank my family for their unwavering support. I wouldn't be here without the love of my parents, Cindy and Chris, my sister, Madeleine, and my aunt, Nikki. As with everything, your care rendered any challenge manageable, providing necessary perspective when I had a tendency to get in my own head. My greatest champions, who all helped nurture a curiosity and interest in science, my grand-parents: Fiona, Richard, Jean, and Harry. My in-laws, Bruno and Christine, could not have been bigger cheerleaders from before the PhD was even a possibility. Words cannot describe my appreciation for the generosity offered during every step of the last 8 years. And finally, I would like to thank my wife, Caroline. You are truly my better half. Deciding to attend that one, and only, early-morning triathlon training session was by far the best decision I ever made. I feel so privileged to have been your companion through the mundane and exciting, witness your grace and strength during trying times, and I can't see what adventures lie ahead for us.

The work detailed in this dissertation was generously supported by: the Office of the Provost and the Clinical Translational Science Institute, Huck Life Sciences Institute, and the Social Science Research Institutes at the Pennsylvania State University; the National Center for Advancing Translational Sciences, National Institutes of Health; Gavi, the Vaccine Alliance; the Bill & Melinda Gates Foundation; the National Science Foundation; and the University Graduate Fellowship at the Pennsylvania State University. Findings and conclusions do not necessarily reflect the view of the funding agencies.