## CONTENTS

Acknowledgments ..... 3
Introduction ..... 4
Evolving Monkey ..... 5
The Past and Present ..... 5
The Future ..... 7
Use This Book ..... 8
1 Compilers \& Virtual Machines ..... 10
Compilers ..... 11
Virtual and Real Machines ..... 14
Real Machines ..... 14
What Is a Virtual Machine? ..... 19
Why Build One? ..... 21
Bytecode ..... 23
What We're Going to Do, or: the Duality of VM and Compiler ..... 24
2 Hello Bytecode! ..... 26
First Instructions ..... 27
Starting With Bytes ..... 28
The Smallest Compiler ..... 32
Bytecode, Disassemble! ..... 37
Back to the Task at Hand ..... 41
Powering On the Machine ..... 43
Adding on the Stack ..... 49
Hooking up the REPL ..... 54
3 Compiling Expressions ..... 57
Cleaning Up the Stack ..... 57
Infix Expressions ..... 61
Booleans ..... 65
Comparison Operators ..... 69
Prefix Expressions ..... 76
4 Conditionals ..... 82
Jumps ..... 85
Compiling Conditionals ..... 87
Executing Jumps ..... 99
Welcome Back, Null! ..... 102
5 Keeping Track of Names ..... 110
The Plan ..... 111
Compiling Bindings ..... 112
Introducing: the Symbol Table ..... 114
Using Symbols in the Compiler ..... 117
Adding Globals to the VM ..... 120
6 String, Array and Hash ..... 125
String ..... 125
Array ..... 130
Hash ..... 134
Adding the index operator ..... 140
7 Functions ..... 146
Dipping Our Toes: a Simple Function ..... 146
Representing Functions ..... 146
Opcodes to Execute Functions ..... 148
Compiling Function Literals ..... 150
Compiling Function Calls ..... 163
Functions in the VM ..... 166
A Little Bonus ..... 175
Local Bindings ..... 176
Opcodes for Local Bindings ..... 177
Compiling Locals ..... 180
Implementing Local Bindings in the VM ..... 191
Arguments ..... 199
Compiling Calls With Arguments ..... 200
Resolving References to Arguments ..... 205
Arguments in the VM ..... 207
8 Built-in Functions ..... 216
Making the Change Easy ..... 217
Making the Change: the Plan ..... 222
A New Scope for Built-in Functions ..... 223
Executing built-in functions ..... 227
9 Closures ..... 233
The Problem ..... 234
The Plan ..... 235
Everything's a closure ..... 236
Compiling and resolving free variables ..... 246
Creating real closures at run time ..... 257
Recursive Closures ..... 261
10 Taking Time ..... 273
Resources ..... 277
Feedback ..... 279
Changelog ..... 280

