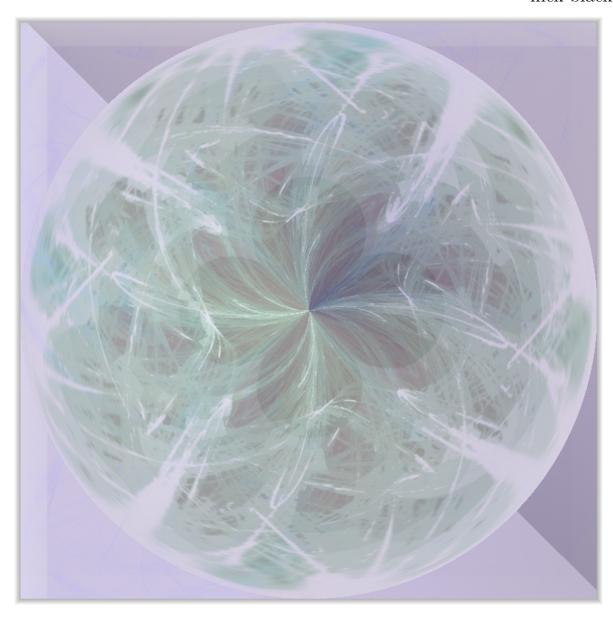
the finest machine the science and the joy of computing

nick black



DEDICATED to my professors, my students, and my friends at the Georgia Institute of Technology, who give rise to that spirit living in his machinis ex deis. Hack on, lads, hack on!

TO ALL THOSE who took a wary chance on a risky bet, especially Coach Jeanette Martin: thanks for everything. You made possible this work of tightly-controlled audacity. Per ardua ad astra.

—Atlanta, 2012

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I made a discovery today. I found a computer... And then it happened... a door opened to a world... rushing through the phone line like heroin through an addict's veins, an electronic pulse is sent out, a refuge from the day-to-day... This is it, this is where I belong.

—The Mentor, "The Hacker Manifesto" Phrack Vol. One, Issue Seven, Phile 3 (1986-09-25)

Something else gets under your skin, keeps you working days and nights at the sacrifice of your sleeping and eating and attention to your family and friends, something beyond the love of puzzle solving. And that other force is the anticipation of understanding something about the world that no one has ever understood before you... I have experienced that pleasure of discovering something new. It is an exquisite sensation, a feeling of power, a rush of the blood, a sense of living forever. To be the first vessel to hold this new thing.

All of the scientists I've known have at least one more quality in common: they do what they do because they love it, and because they cannot imagine doing anything else. In a sense, this is the real reason a scientist does science. Because the scientist must. Such a compulsion is both blessing and burden. A blessing because the creative life, in any endeavor, is a gift filled with beauty and not given to everyone, a burden because the call is unrelenting and can drown out the rest of life.

This mixed blessing and burden must be why the astrophysicist Chandrasekhar continued working until his mid-80's, why a visitor to Einstein's apartment in Bern found the young physicist rocking his infant with one hand while doing mathematical calculations with the other. This mixed blessing and burden must have been the "sweet hell" that Walt Whitman referred to when he realized at a young age that he was destined to be a poet. "Never more," he wrote, "shall I escape."

—Alan Lightman, "Spellbound by the Eternal Riddle, Scientists Revel in Their Captivity", New York Times (2003-11-11)

Part of the inhumanity of the computer is that, once it is competently programmed and working smoothly, it is completely honest. I do not fear computers. I fear the lack of them.

-Isaac Asimov, source unknown

Nature does not know extinction; all it knows is transformation. Everything science has taught me, and continues to teach me, strengthens my belief in the continuity of our spiritual existence.

—Wernher Von Braun, "Why I Believe in Immortality", as quoted in Thomas Pynchon's Gravity's Rainbow (1973), from The Third Book of Words to Live By, W. Nichols (ed.) (1962)

In the particular is contained the universal.

—Anton Chekhov, as quoted by James Joyce in Arthur Power's From the Old Waterford House (1949)

There may indeed be other applications of the system than its use as a logic.

-Alonzo Church,

The Calculi of Lambda-Conversion (1932)

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| | "Die ganze Zahl schuf der liebe Gott, alles Ubrige ist Menschenwerk." ("God made the integers; the rest is the work of man.") —Leopold Kronecker, as quoted in H. Weber's "Leopold Kronecker", Mathematische Annalen Vol. 43, No. 1 (1892) | | |
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"All physical systems can be thought of as registering and processing information, and how one wishes to define computation will determine your view of what computation consists of."

-Seth Lloy

"Ultimate Physical Limits to Computation", Nature 406 (2000-08-31) 10 Hierarchy theory of Chomsky. Deterministic and nondeterministic machines. Turing's Machine, Curry's combinatory logic, and Church's λ-calculus. The Church-Turing Thesis. Information-theoretic limita-31 tions of formal systems. 11 Uncomputable functions. Polynomial and Exponential hierarchies. Reductions of Karp and Levin. The class of dashed hopes and idle dreams. Machine-oblivious analysis of algorithms. 33 12 Fixed and floating point. Counting quickly. Numerical approximations and stabilities. Well-conditioned 35 algorithms. The bounding, detection, and correction of errors. 13 Computation elements. Real algorithm analysis. Brent's Theorem and Gustafson's Law. 37 14 Lloyd's limit. Kolmolgorov complexity, algorithmic information theory and Chaitin's Constant. Schmid-39 huber's Super- Ω and Speed Prior. 15 Queueing theory of Kleinrock. Baran and distributed communication. Quantum computing, BQP, and spaces of infinitely many dimensions. 41 16 Pseudorandom numbers and pseudorandomized algorithms. The quantum tarpits of reversible com-43 putation and Brownian machines. 17 Programming language theory. Compilation. Security and the undecidability of static analysis. 45 18 Code as data. Von Neumann's revenge. Self-modifying code and genetics. Binding and reduction. The joy of LISP. Dijkstra's revenge. 47 IVTHE INELUCTABLE MODALITY OF STATE. 49 "μεταβάλλον ἀναπαύεται." ("Even while it changes, it stands still.") - Ἡράχλειτος (Heraclitus the Ephesian), as quoted in Abelson and Sussman's The Structure and Interpretation of Computer Programs (Second Edition, 1996) 19 The persistence of information and remembrance of things past. Search. Data structures. **51** 20 Communication networks. Hypercubes, butterflies and banyans. Infinity machines, and their limitations. 53 21 Indexing. Fractal structure and Hausdorff dimension of data. Compression. Address spaces and content-addressed memories. 55 22 Memory architecture. Remembering quickly. Offline and online algorithms. Infinite representations. 57 23 The complexity of state and the nature of time. Spacetime and statetime: transformations among space, state, time and portability. Is computation energy? **59** 24 Parallelism among bits, registers, instructions, memories, and threads. The Taxonomy of Flynn. Hardware absurdities. 61 25 Dataflow and transport-triggered architectures. Out-of-order processors. Coherent and incoherent

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26 ACID and relational databases. Transactional memory. Ferromagnetic and plastico-optical storage.

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V CONSILIENCE. 67

"Die Welt ist alles, was der Fall ist... Wovon man nicht sprechen kann, darüber muβ man schweigen." ("The world is all that is the case. Whereof one cannot speak, one must remain silent.")

—Ludwig Wittgenstein Tractalus Logi

(1010)

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| | —Ludwig Wittgenstein, Iractatus Logico-Philosophicus (1918) | |
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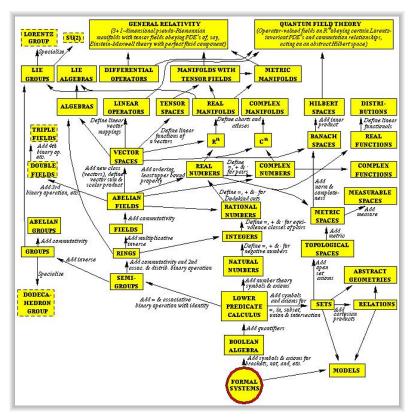


Figure 0.1: "What Goes on at the Top?" Max Tegmark, 2001. Used with permission.