Quantum Computation

A Glimpse Into the Future of Computing

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Richard Gordon

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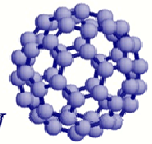

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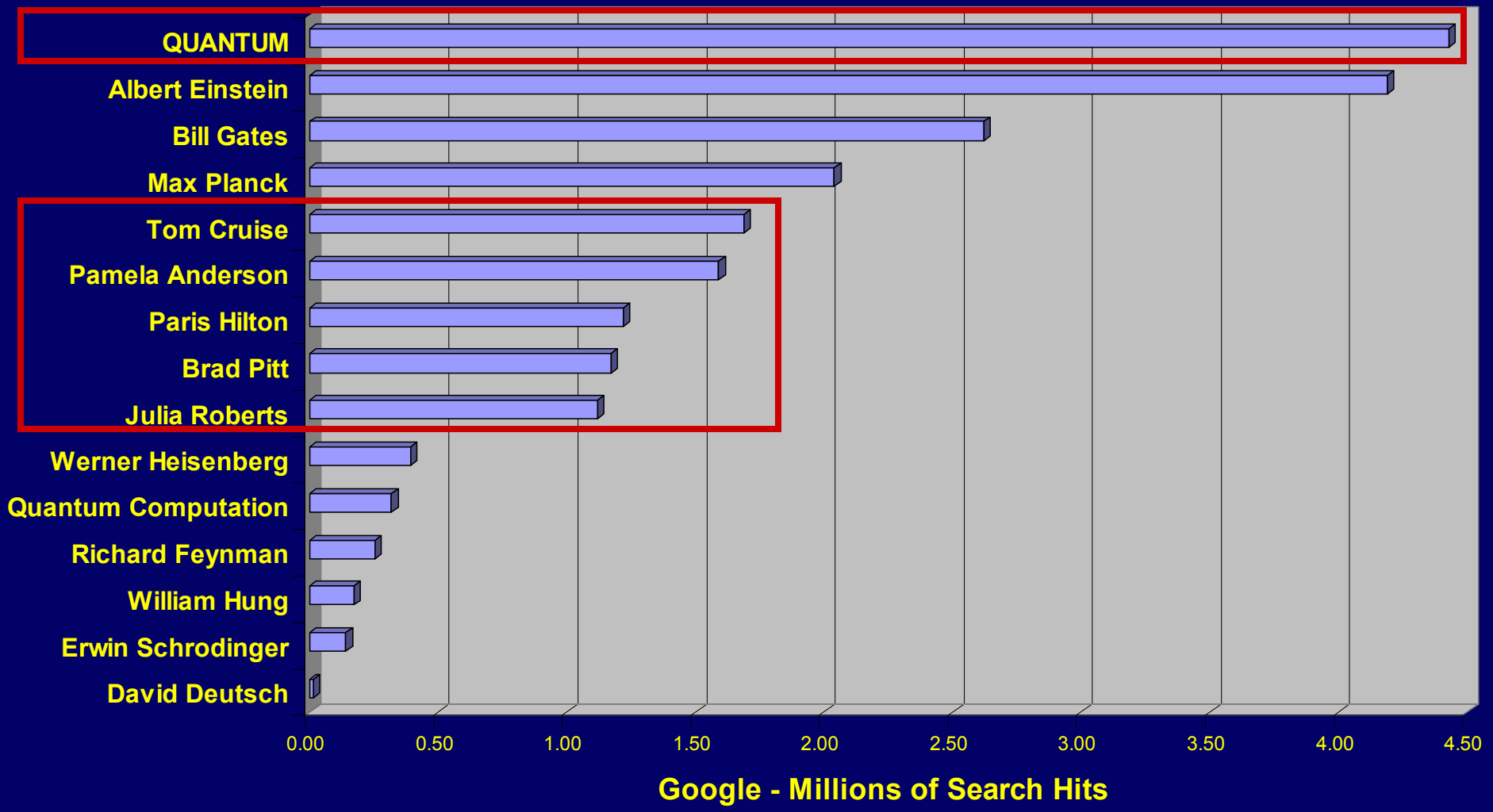
Agenda

- Introduction
  - Richard Gordon
- *Quantum |101>*
  - Dr. Collin Williams
- JPL
  - Dr. Colin Williams
- D-Wave Systems
  - Dr. Geordie Rose
- NEC Fundamental Research Labs
  - Dr. Shen Tsai
- UC Berkeley, BQIC
  - Prof. Umesh Vazirani
- HP Laboratories
  - Dr. Tad Hogg

Quantum is Sexy



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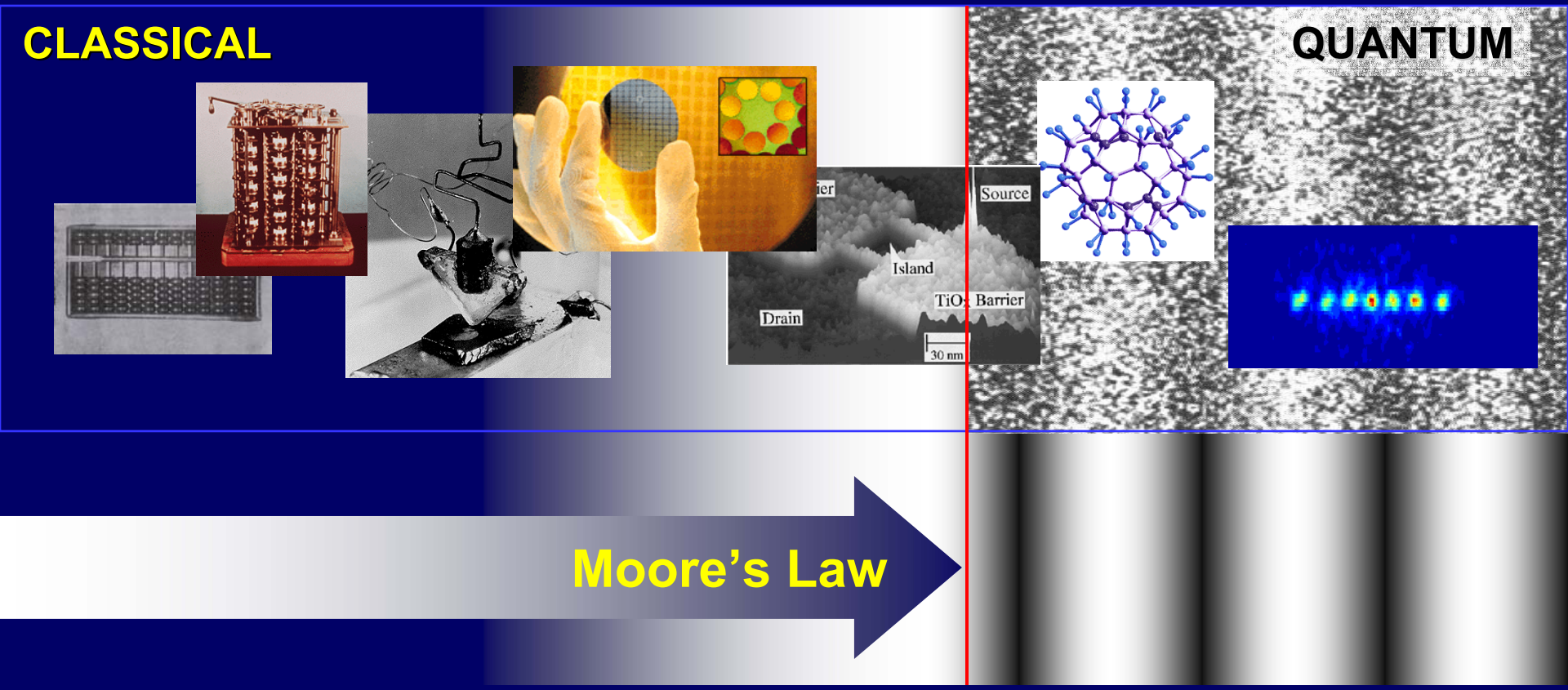
Quantum is Inevitable

- Thanks for everything Gordon Moore … it's been a great run



Source: Artur Ekert

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Quantum is Strange

- Richard Feynman -

"If you think you understand quantum mechanics, you don't understand quantum mechanics.

Do not [ask], if you can possibly avoid it, 'But how can it be like that?' because you will go 'down the drain' into a blind alley from which nobody has yet escaped. Nobody knows how it can be like that."

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Quantum Information is Different

Information is Physical

- Information processing (computing) is a physical process
- Information has energy
- Information can't travel faster than the speed of light
- Quantum information exists in parallel
- Quantum information obeys Heisenberg Uncertainty
- Quantum information is unique and can't be copied
- Quantum information can be teleported

Quantum Computation is Everywhere

QC Approach	The DiVincenzo Criteria							
	Quantum Computation						QC Networkability	
	#1	#2	#3	#4	#5		#6	#7
NMR								
Trapped Ion								
Neutral Atom								
Cavity QED								
Optical								
Solid State								
Superconducting								
Unique Qubits	This field is so diverse that it is not feasible to label the criteria with "Promise" symbols.							

Legend: = a potentially viable approach has achieved sufficient proof of principle

 = a potentially viable approach has been proposed, but there has not been sufficient proof of principle

 = no viable approach is known

QC ROADMAP: http://qist.lanl.gov

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Quantum Computation is Hard

- Development timeline
  - Mastery will be measured in decades
  - Baby steps happening now
- Many challenges
  - Decoherence
  - Entanglement
  - Isolation
  - Error correction
  - Algorithm development

Nature: 17 June 2004

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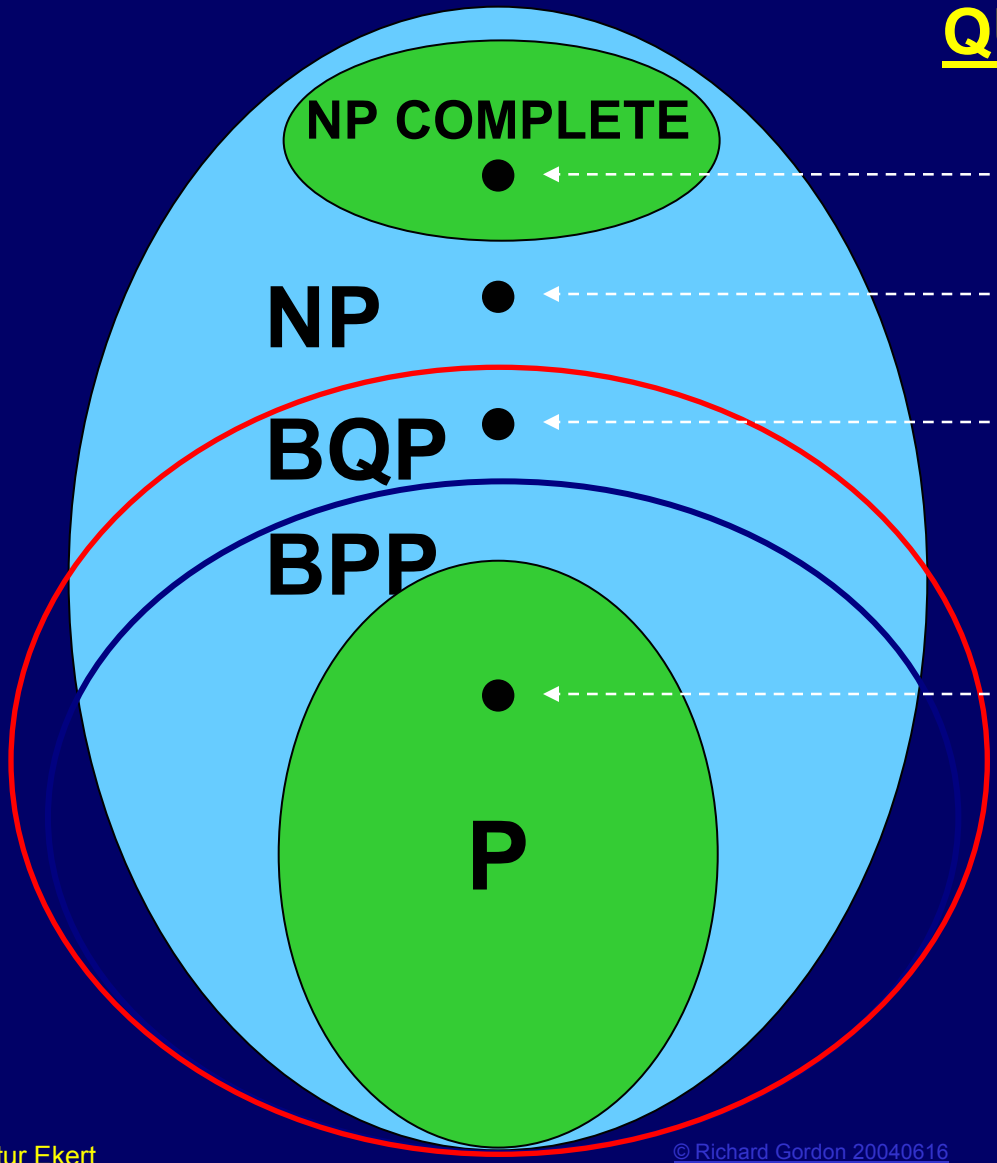
Quantum Computation is Powerful



COMPLEXITY ⇨

QUANTUM ALGORITHMS

- 3 SAT
- Graph Isomorphism
- Factoring
- Multiplication

Source: Artur Ekert

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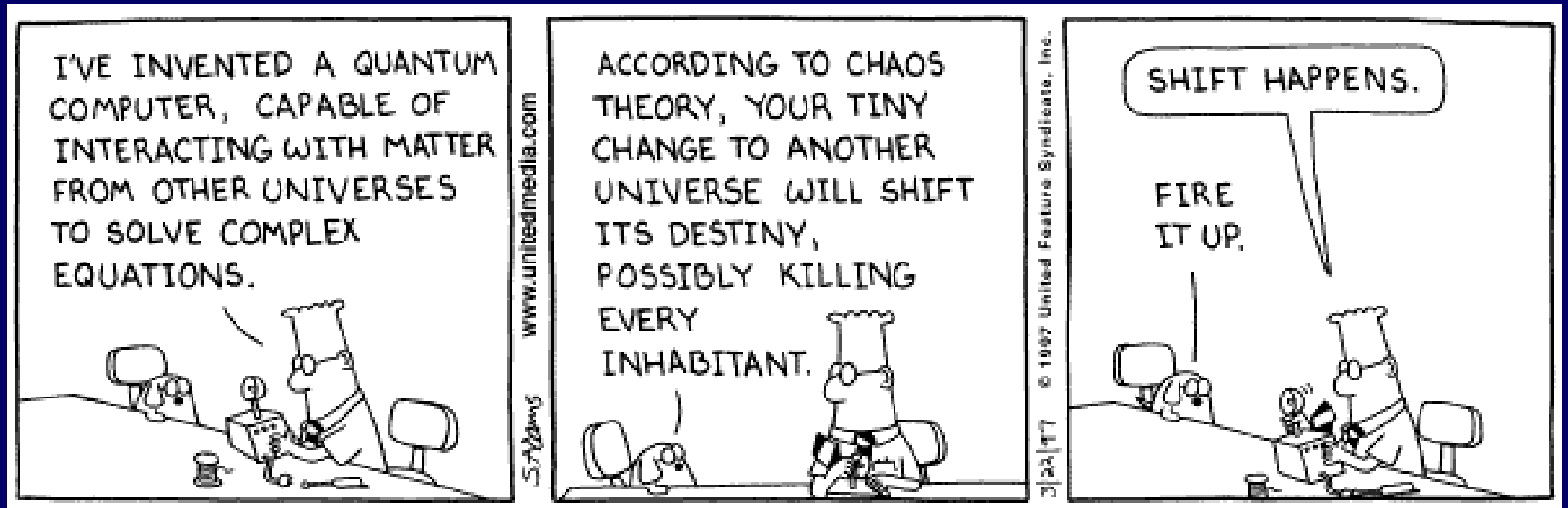
Quantum Computation is a Paradigm Shift



Dr. Colin Williams

- Senior Research Scientist, Program Manager for Advanced Computing Paradigms, Information Technology Program Office, JPL, Cal Tech
  - Quantum Computing Technologies Group, 1998
- Author 5 books, including two on quantum computing
  - *Explorations in Quantum Computing,* Telos Press, 1997
  - *Ultimate Zero and One,* Copernicus Books, 1999
- Teacher
  - Stanford University, 2000 – 2002, Associate Professor of Computer Science
- Current research
  - Quantum algorithms for solving computationally hard problems
- Patents
  - Quantum computing circuit synthesis and mapping
  - Quantum lithography
- Ph.D. in artificial intelligence, University of Edinburgh
- M.Sc. and D.I.C. in atmospheric physics and dynamics, Imperial College, University of London
- B.Sc. in mathematical physics,University of Nottingham

Dr. Geordie Rose

- Co-founder, President and CEO of D-Wave Systems, Vancouver, Canada
- Co-inventor on 24 filed patents in the field of superconducting electronics
- Co-author eight peer-reviewed scientific articles
- 2001 *Business in Vancouver 40 Under 40* award
- 2002 BCTIA award for Most Promising Start-Up
- Raised over $20M for D-Wave, including US$7.1M led by Draper Fisher Jurvetson, June 2003
- Ph.D. in theoretical physics, University of British Columbia
- B.Eng. in engineering physics, McMaster University

Dr. Shen Tsai

- Research Fellow at NEC Fundamental Research Labs
  - Leads Josephson-junction-based qubit project
  - Physics and technology of Josephson effects
  - Single-electron transport phenomena
  - Quantum coherence in superconducting tunneling systems
- Quantum breakthroughs
  - First solid-state based qubit in 1999
  - First solid-state quantum CNOT gate in 2003
  - Efficient single-shot readout in 2004
- Head of the Macroscopic Quantum Coherence Laboratory, Physical and Chemical Institute (Riken)
- Group Leader of the CREST Quantum Information Project
- Ph.D. in physics, SUNY Stony Brook, 1983
- B.S., Physics Department, UC Berkeley, 1975
- Fellow of the American Physical Society

Prof. Umesh Vazirani

- Faculty at U.C. Berkeley since 1987
  - Miller Research Professor in 2000
  - Director of BQIC - the Berkeley Center for Quantum Information and Computation
- Author
  - *An Introduction to Computational Learning Theory*, MIT Press, with Michael Kearns
- Ph.D. in computer science, U.C. Berkeley, 1985
- B.Tech in computer science, M.I.T., 1981

Dr. Tad Hogg

- Member of the Information Dynamics Group, HP Laboratories
- Quantum research
  - Applications
  - Quantum algorithm behavior visualization software
    - http://www.hpl.hp.com/shl/projects/quantum/demo
  - Survey of quantum search algorithms, IEEE Intelligent Systems, July/August 1999
    - (http://www.computer.org/intelligent/ex1999/pdf/x4009.pdf)
- Ph.D., Stanford University
- B.S., California Institute of Technology

Questions and Discussion

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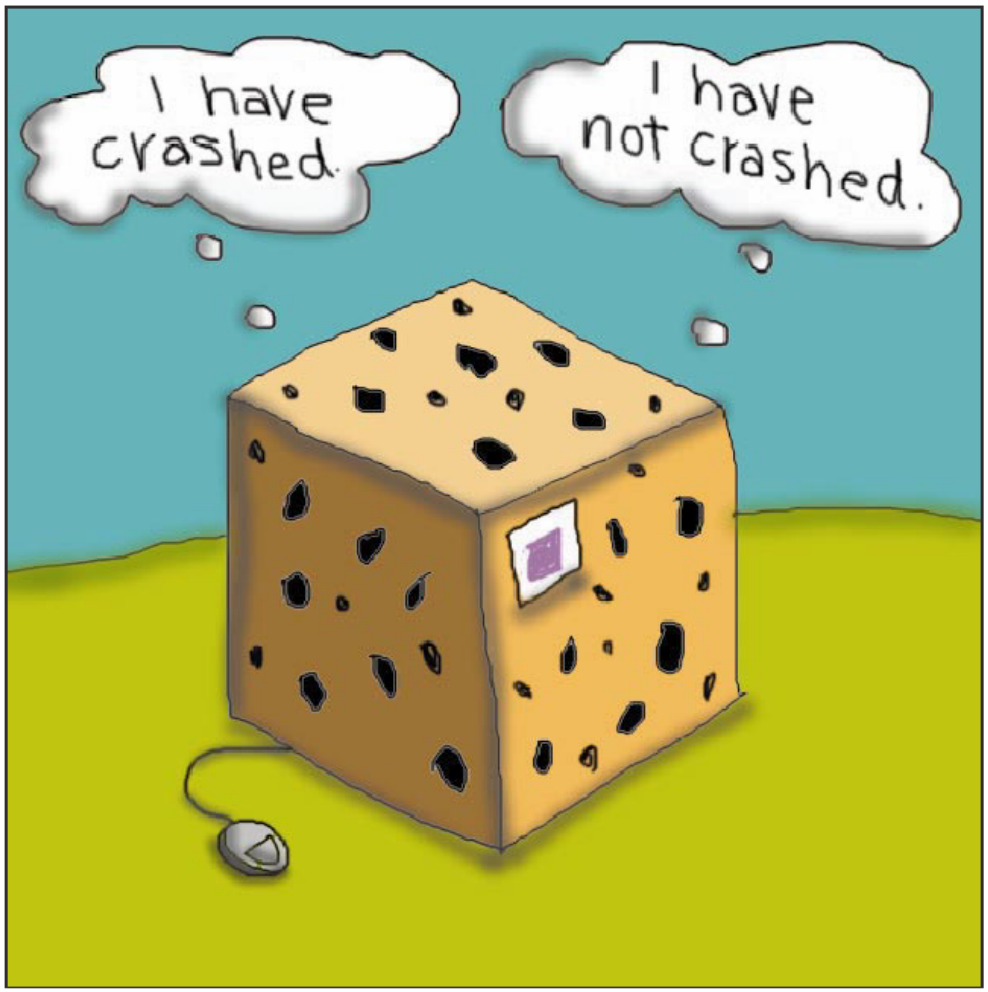

Schrödinger's computer. —Sally O. Lee