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# The Beauty and Joy of Computing

## Lecture #24 Future of Computing



### Amazon Prime Air!

**Good:** Deliver to your home in 30 minutes after click

**Bad:** Drones all over the air? Seriously?



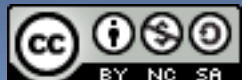
[www.washingtonpost.com/blogs/the-switch/wp/2013/12/01/  
amazon-wants-to-deliver-packages-in-30-minutes-with-  
drones/](http://www.washingtonpost.com/blogs/the-switch/wp/2013/12/01/amazon-wants-to-deliver-packages-in-30-minutes-with-drones/)



# Lecture Overview

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- Where will today's computers go?
- Quantum Computing
- DNA Computing
- Biological Machines





# Computer Technology - Growth!

## ■ Processor

- Speed 2x / 2 years (since '71)
- 100X performance last decade
- When you graduate: 3 GHz, 32 Cores

## ■ Memory (DRAM)

- Capacity: 2x / 2 years (since '96)
- 64x size last decade.
- When you graduate: 128 GibiBytes

## ■ Disk

- Capacity: 2x / 1 year (since '97)
- 250X size last decade.
- When you graduate: 16 TeraBytes

Kilo ( $10^3$ ) & Kibi ( $2^{10}$ )



Mega ( $10^6$ ) & Mebi ( $2^{20}$ )



Giga ( $10^9$ ) & Gibi ( $2^{30}$ )



Tera ( $10^{12}$ ) & Tebi ( $2^{40}$ )



Peta ( $10^{15}$ ) & Pebi ( $2^{50}$ )



Exa ( $10^{18}$ ) & Exbi ( $2^{60}$ )



Zetta ( $10^{21}$ ) & Zebi ( $2^{70}$ )



Yotta ( $10^{24}$ ) & Yobi ( $2^{80}$ )





# Peer Instruction



What was recently proposed to go after Yotta?  
(i.e.,  $10^{27}$ )

- a) Lotta
- b) Lotsa
- c) Wholelotta
- d) Hella
- e) Zillion

**Both Google's and WolframAlpha's calculator can understand  
and use "Hella" in their calculations!**

[www.makehellaofficial.blogspot.com](http://www.makehellaofficial.blogspot.com)





# Kilo, Mega, Giga, Tera, Peta, Exa, Zetta, Yotta

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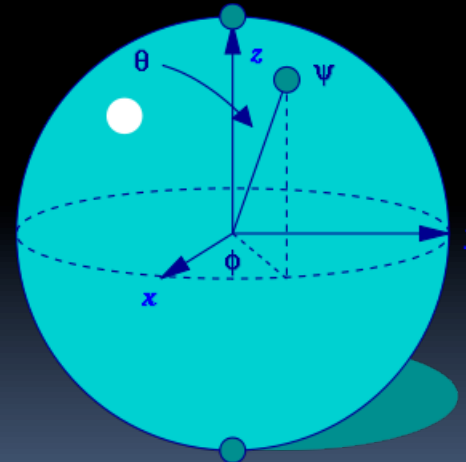
- Kid meets giant Texas people exercising zen-like yoga. – Rolf O
- Kind men give ten percent extra, zestfully, youthfully. – Hava E
- Kissing Mentors Gives Testy Persistent Extremists Zealous Youthfulness. – Gary M
- Kindness means giving, teaching, permeating excess zeal yourself. – Hava E
- Killing messengers gives terrible people exactly zero, yo
- Kindergarten means giving teachers perfect examples (of) zeal (&) youth
- Kissing mediocre girls/guys teaches people (to) expect zero (from) you
- Kinky Mean Girls Teach Penis-Extending Zen Yoga
- Kissing Mel Gibson, Teddy Pendergrass exclaimed: “Zesty, yo!” – Dan G
- Kissing me gives ten percent extra zeal & youth! – Dan G (borrowing parts)





# Quantum Computing (1)

- Proposed computing device using quantum mechanics
  - This field in its infancy...
- Normally: **bits**, which are either 0 or 1
- Quantum: **qubits**, either 0, 1 or “quantum superposition” of these
  - This is the key idea
- If you have 2 bits, they’re in exactly one of these:
  - 00, 01, 10 or 11
- If you have 2 qubits, they’re in **ALL** these states with varying probabilities



A Bloch sphere is the geometric representation of 1 qubit

[en.wikipedia.org/wiki/Quantum\\_computer](https://en.wikipedia.org/wiki/Quantum_computer)





# Quantum Computing (2)

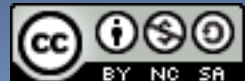
- **Imagine a problem with these four properties:**
  - The only way to solve it is to guess answers repeatedly and check them,
  - There are  $n$  possible answers to check,
  - Every possible answer takes the same amount of time to check, and
  - There are no clues about which answers might be better: generating possibilities randomly is just as good as checking them in some special order.
- ...like trying to crack a password from an encrypted file
- **A normal computer**
  - would take (in the worst case)  $n$  steps
- **A quantum computer**
  - can solve the problem in steps proportional to  $\sqrt{n}$
- **Why does this matter?**





# Quantum Computing (3)

- Say the password is exactly 72 bits (0/1)
- That's  $2^{72}$  possibilities
- Let's say our Mac lab attacked the problem
  - 30 machines/lab \* 8 cores/machine \* 3 GHz (say 3 billion checks per second/core)  
= 720,000,000,000 checks/sec/lab  
= 720 Gchecks/sec/lab
- Regular computers
  - $2^{72}$  checks needed / 720 Gchecks/sec/lab  
 $\approx 6.6$  billion sec/lab  
 $\approx 208$  years/lab
- 72-qubit quantum computers in time  $\propto$  to  $\sqrt{2^{72}} = 2^{36}$ 
  - $2^{36}$  checks needed / 720 Gchecks/sec/lab  
 $\approx 0.1$  sec/lab







# Quantum Computing Explained by Physicists



[www.phdcomics.com/tv](http://www.phdcomics.com/tv)



<http://www.youtube.com/watch?v=T2DXrs0OpHUs>

UC Berkeley "The Beauty and Joy of Computing" : **Future of Computing** (9)

Garcia





# DNA Computing

- **Proposed computing device using DNA to do the work**
  - Take advantage of the different molecules of DNA to try many possibilities at once
  - Ala parallel computing
  - Also in its infancy
- **In 2004, researchers claimed they built one**
  - Paper in "Nature"

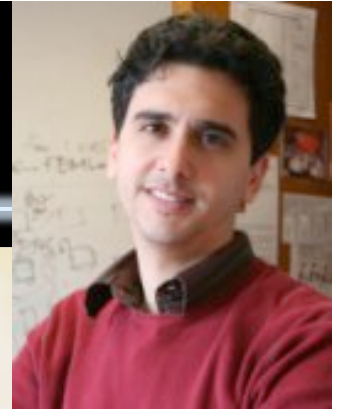


[en.wikipedia.org/wiki/DNA\\_computing](http://en.wikipedia.org/wiki/DNA_computing)



# Biological Machines

- Michel Maharbiz and his team at Cal have wired insects (here a giant flower beetle) and can control flight
  - Implanted as Pupa
- Vision
  - Imagine devices that can collect, manipulate, store and act on info from environment





# Peer Instruction



## What is the most exciting future for computing?

- a) Incremental improvements in computing architectures
- b) Quantum computing
- c) DNA computing
- d) Biological Machines
- e) Something completely different





# Summary

- What a wonderful time we live in; we're far from done
  - What about privacy?
- Find out the problem you want to solve
  - Computing can and will help us solve it
- We probably can't even imagine future software + hardware breakthroughs

