



iCyPhy



# The Coevolution of Humans and Machines

*Edward A. Lee*

**UC Berkeley**

*Invited talk in "Penser les technosciences" series,  
LAAS, Toulouse, Feb. 5, 2020*

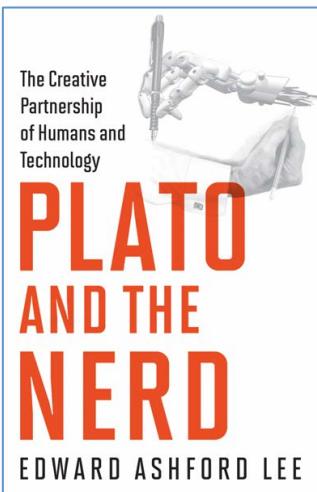


**University of California at Berkeley**



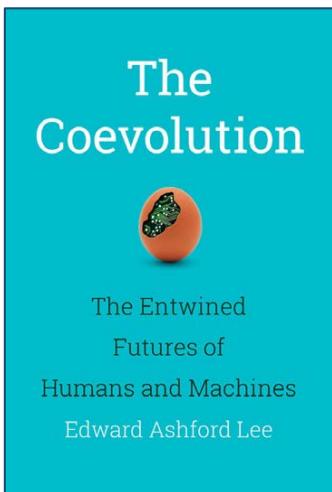
# The (Very Short) Summary

We humans have less control than we think over technology development.



MIT Press, 2017   MIT Press, 2020

Lee, Berkeley



Implications: Policy is more important and more difficult to make effective than it might seem.



## A Scenario: “Information Apocalypse”

- Assumption: All information on the Internet is “true.”
- Fact: Information flux today vastly exceeds individual human capacity to absorb it.
- Fact: Individualized information flows, regulated by software, compete for attention.
- Result: “Islands of disjoint truths.”
- *Is this the result of deliberate technology design?*



# *Digital Creationism: The Hypothesis that Technology is Top-Down Intelligent Design*



“Every boat is copied from another boat ... Let's reason as follows in the manner of Darwin. It is clear that a very badly made boat will end up at the bottom after one or two voyages and thus never be copied. ... One could then say, with complete rigor, that it is the sea herself who fashions the boats, choosing those which function and destroying the others.”

French philosopher Alain

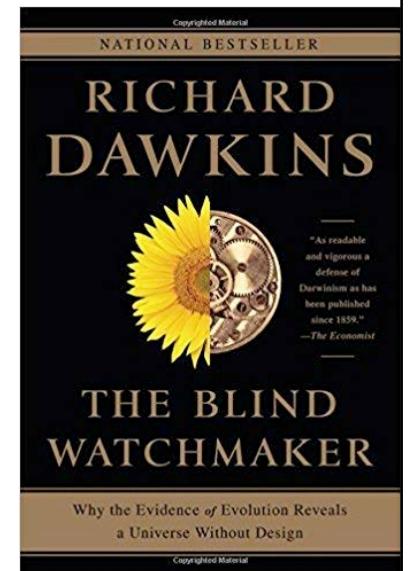


# An Alternative to Digital Creationism: Darwinian Evolution



Evolutionary processes are capable of much more complex and sophisticated design than top-down intelligent design.

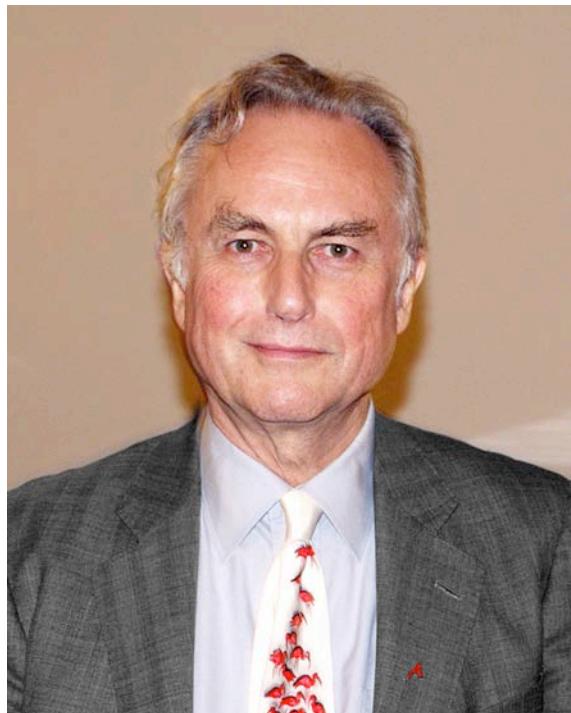
Donan.raven [CC BY-SA 3.0]





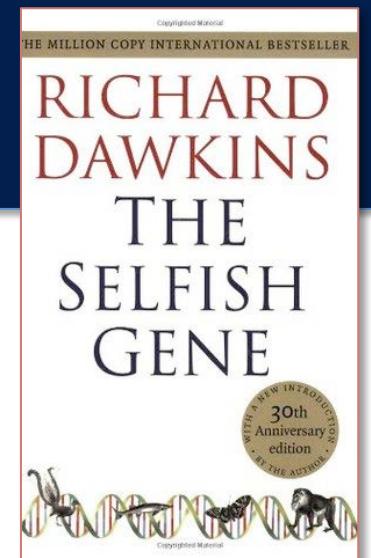
# Eggs and Chickens

Richard Dawkins



Lee, Berkeley

“A chicken is an egg's way  
of making another egg.”



*Is a human a computer's way  
of making another computer?*



## Or is it a *Coevolution*?

Google's million-plus servers are a "collective, metazoan organism."

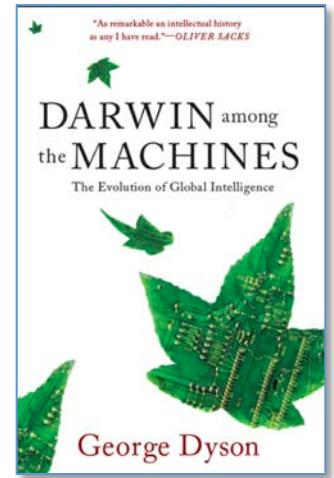
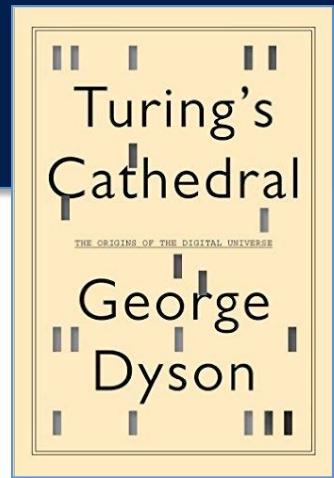
"The companies and individuals who nurture [the servers] are ever more richly rewarded in return"

"Unemployment is pandemic among those not working on behalf of the machines."

"The Big Computer [is] doing everything in its power to make life as comfortable as possible for its human symbionts."

(Dyson, 2012, p. 308,313,325)

Lee, Berkeley





# The Human Role in Technology Development

“We are the sources of mutation in a Darwinian coevolution.”

“We do not like seeing our mental cognitive processes as themselves cogs in a relentless purposeless evolution. But is this what they are?”

The  
Coevolution



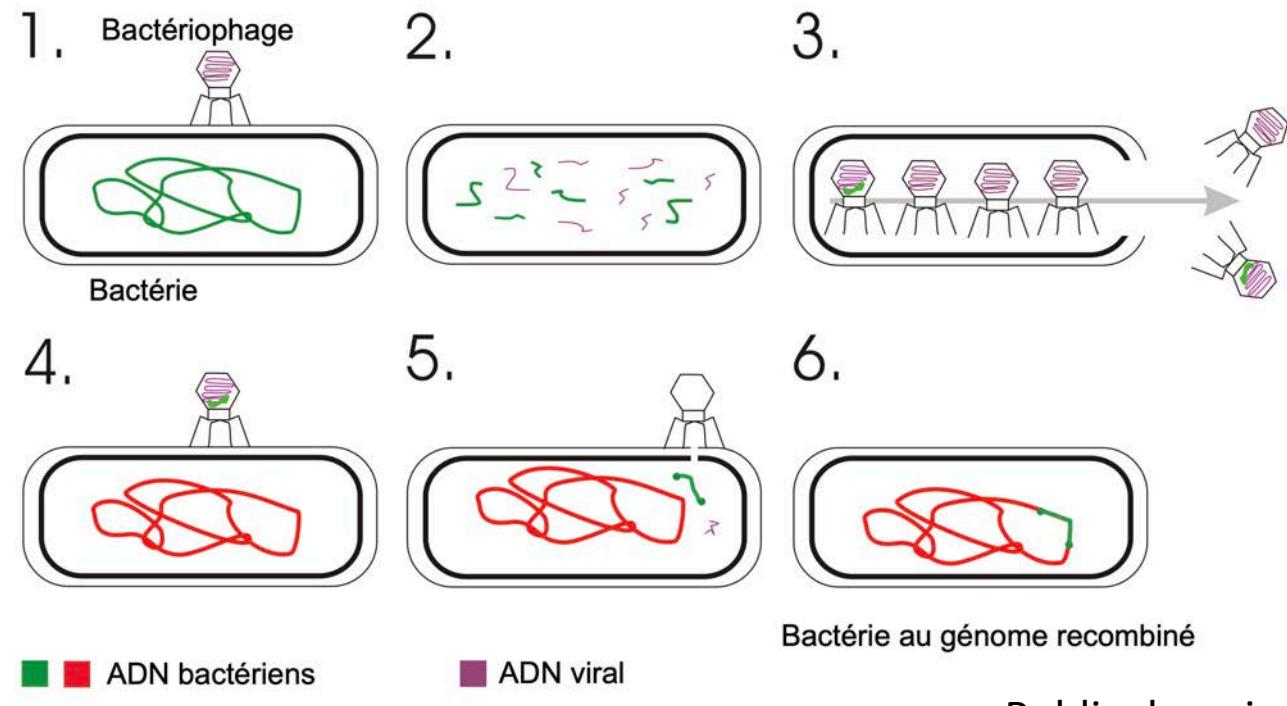
The Entwined  
Futures of  
Humans and Machines  
Edward Ashford Lee

MIT Press, 2020



# Mutation is Not as Random as We Used to Think.

HGT: Horizontal  
Gene Transfer:  
A key factor in  
the evolution of  
antibiotic-resistant  
bacteria.



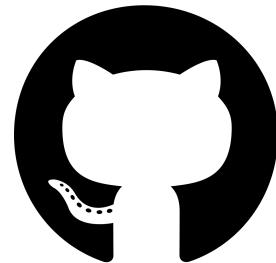
Bactérie au génome recombiné

Public domain



# Humans As Sources of Mutation

## Horizontal Code Transfer (HCT)



**GitHub**

**STL  
Java Library  
Python Modules  
JS Modules**



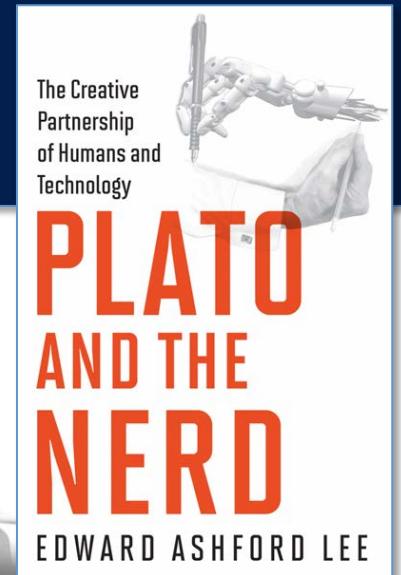
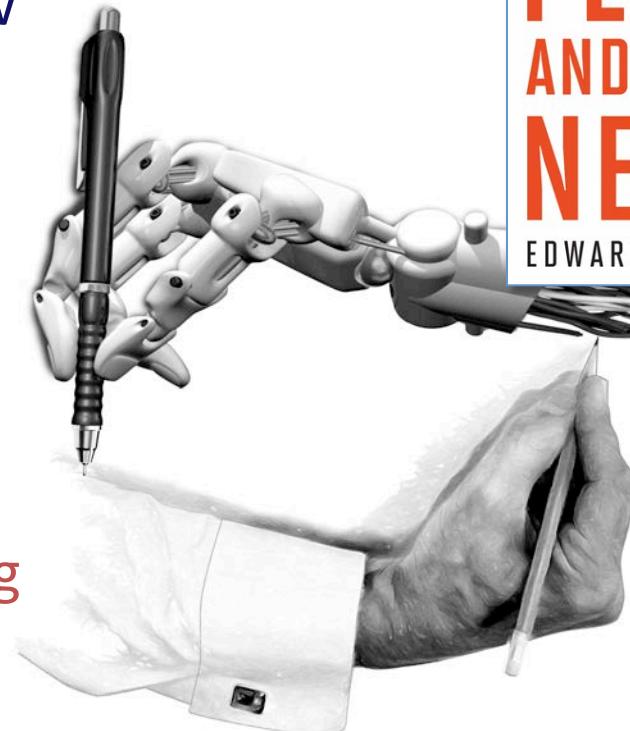
**Virus?**



## An Alternative to Digital Creationism: Symbiotic Coevolution

“Are we playing God, creating a new life form in our own image, or are we being played by a Darwinian evolution of a symbiotic new species?”

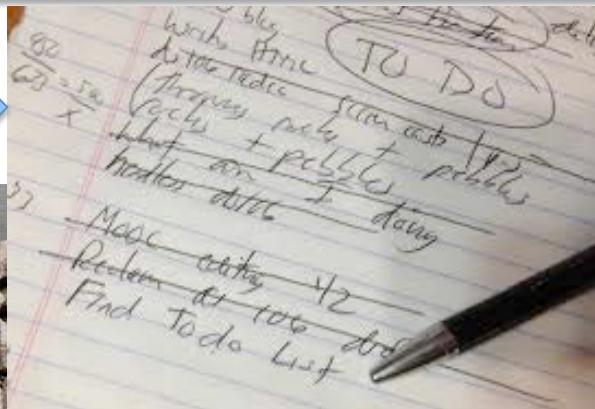
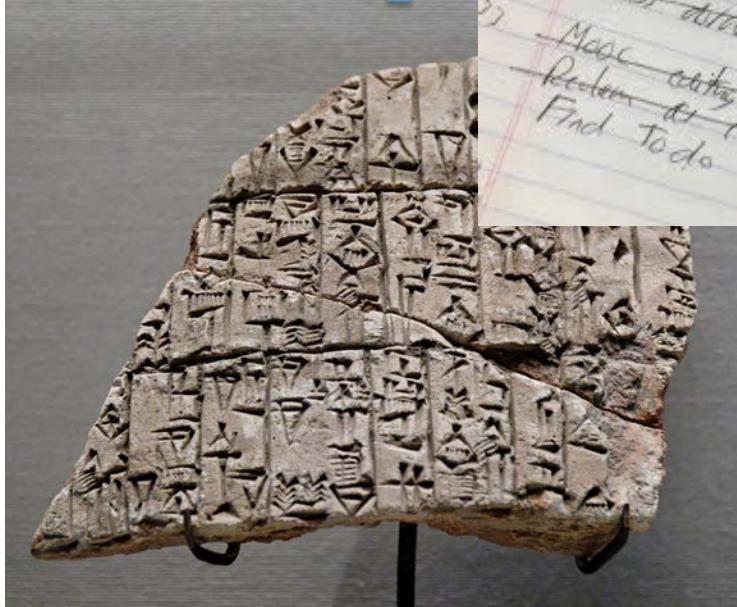
“Are humans the purveyors of the ‘noisy channel’ of mutation, facilitating sex between software beings by recombining and mutating programs into new ones?”



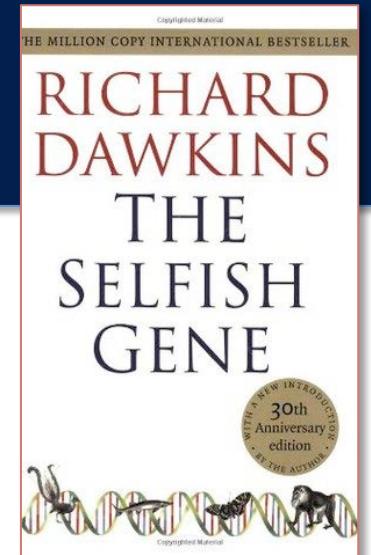
MIT Press  
2017



# The Human Side of This Coevolution



Intellectual  
Prosthetics



Human culture and cognition (“memes” per Dawkins) are coevolving with technology.

Our biology is starting to also.

Lee, Berkeley

12



## Symbiosis

“If computers and software form organisms, then they depend on us for their procreation. We provide the husbandry and serve as midwives.

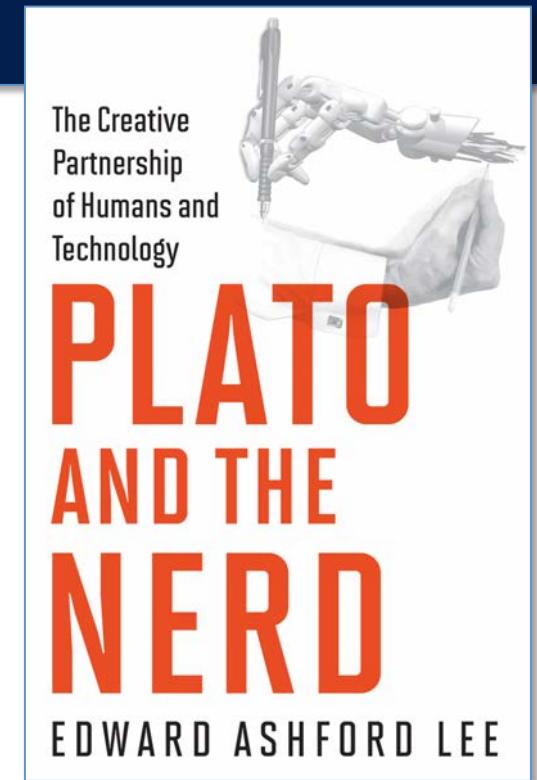
...

The machines make the humans more effective at the very husbandry that spreads the software species.

....

the software survives and evolves only if the company survives and evolves, and vice versa.”

Lee, Berkeley



MIT Press, 2017



# Will We Become Cyborgs?

We are already integrating technology into our biology and our cognition.

Lee, Berkeley

By Unknown Master, Italian (1570s)  
Web Gallery of Art, Public Domain





# Obligate Endosymbiosis



Lee, Berkeley

Lynn Margulis (1938-2011)  
[Photo by Jpedreira, CC BY-SA 2.5]

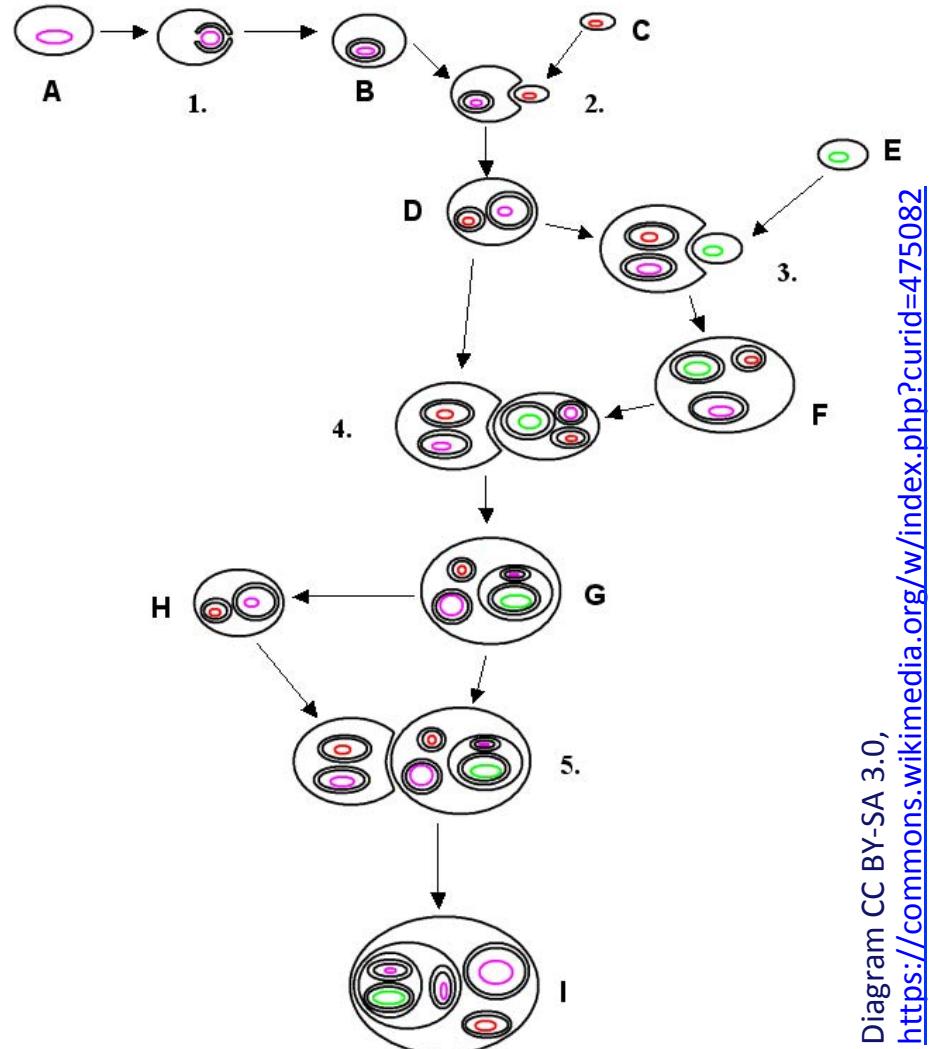


Diagram CC BY-SA 3.0,  
<https://commons.wikimedia.org/w/index.php?curid=475082>



# Hype and Fear About AI

Is AI an *existential threat* to humanity?



Lee, Berkeley



## Three Questions About AIs

1. Are we going to lose control of them?
2. Are they alive?
3. Are they going to match and exceed us?



# A Prerequisite to Losing Control?

Can we teach computers to program?

–Maarten van Steen, March 19, 2019

Can computers teach humans to program?

–Edward Lee, March 20, 2019



# Computers Already Teach Humans to Program

Eclipse  
Jupyter  
Github  
Stack Overflow  
Google

...

Lee, Berkeley

The composite screenshot illustrates how various tools automate parts of the software development process:

- Jupyter Notebook:** Shows a code cell containing a call to Stack Overflow, demonstrating how AI can suggest solutions to specific programming problems.
- Stack Overflow:** A separate window showing a search result for "Lorenz Differential Equations".
- Github Repository:** A browser window showing the repository `icyphy/lingua-franca`. It displays 2 issues, 0 pull requests, and 0 projects.
- Eclipse IDE:** Shows an Eclipse workspace with several Java files. One file, `LinguaFranca.xtext`, contains Xtext-generated code for generating Lingua Franca code from models. The code includes imports for `Xtext 2.17.0`, `java.util.Hashtable`, and a class `LinguaFrancaGenerator` that overrides the `doGenerate` method.

```
2+ * generated by Xtext 2.17.0
4 package org.icyphy.generator
5
6+ import java.util.Hashtable
13
14+ /**
15  * Generates code from your model files on
16  *
17  * See https://www.eclipse.org/Xtext/docume
18  */
19+ class LinguaFrancaGenerator extends Abstrac
20    val importTable = new Hashtable<String,
21
22+   override void doGenerate(Resource resou
23     // First collect all the imports.
24     resource.allContents.filter(Import)
```



## Are Humans in Control of AI?

Are we going to lose control of them?

No.

We never were in control, so we can't lose control.



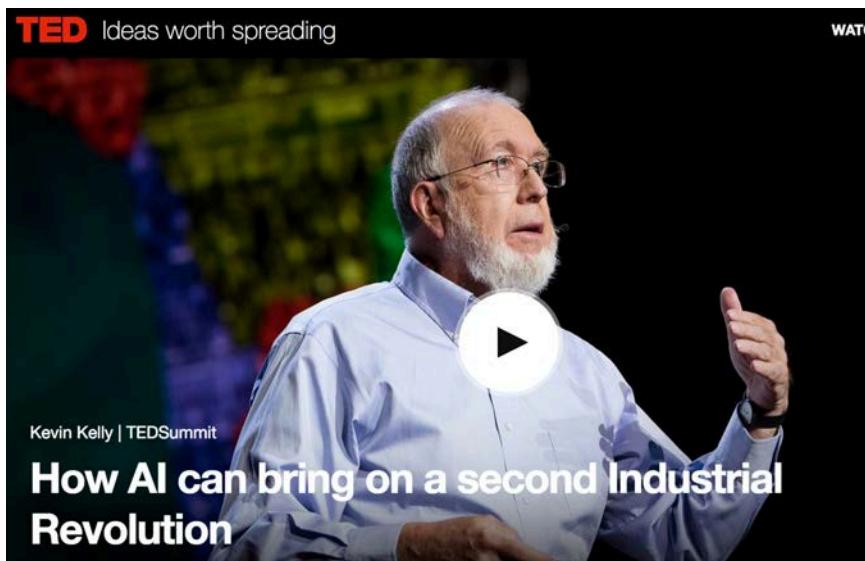
## Three Questions

1. Are we going to lose control of them?
2. Are they alive?
3. Are they going to match and exceed us?

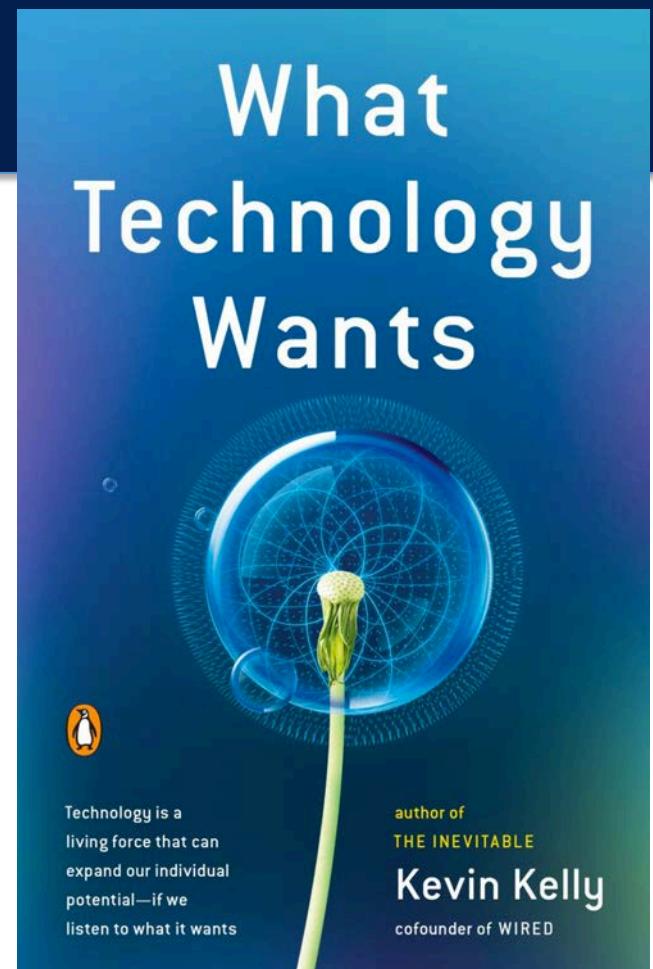


## The Technium

Kevin Kelly, talks about the “technium” as the 7<sup>th</sup> kingdom of life.



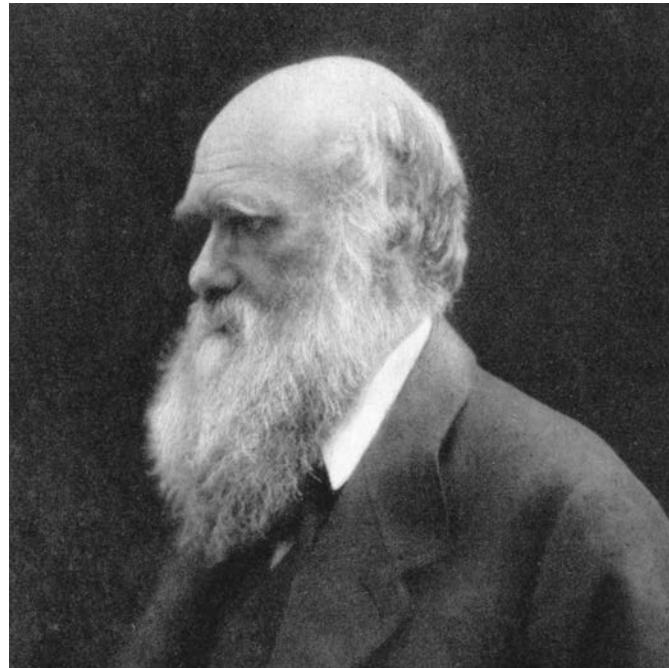
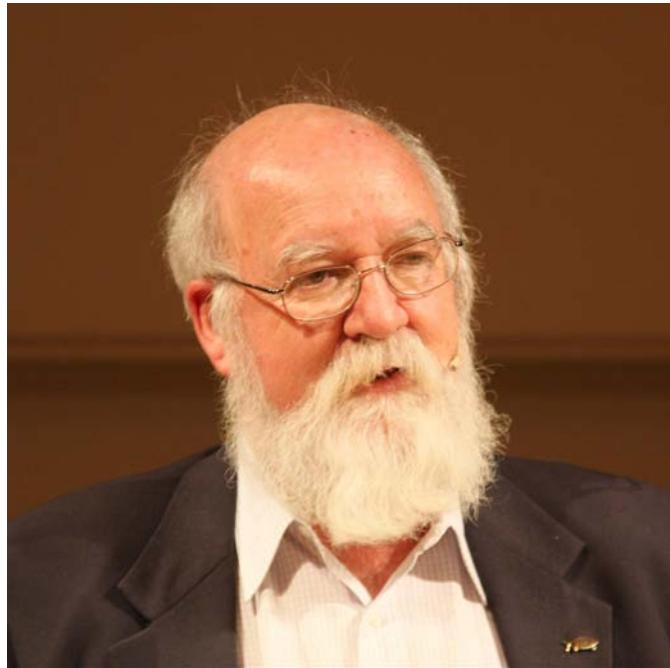
Lee, Berkeley



2010 22



## Daniel Dennett on Life



“It ain’t the meat, it’s the motion.”

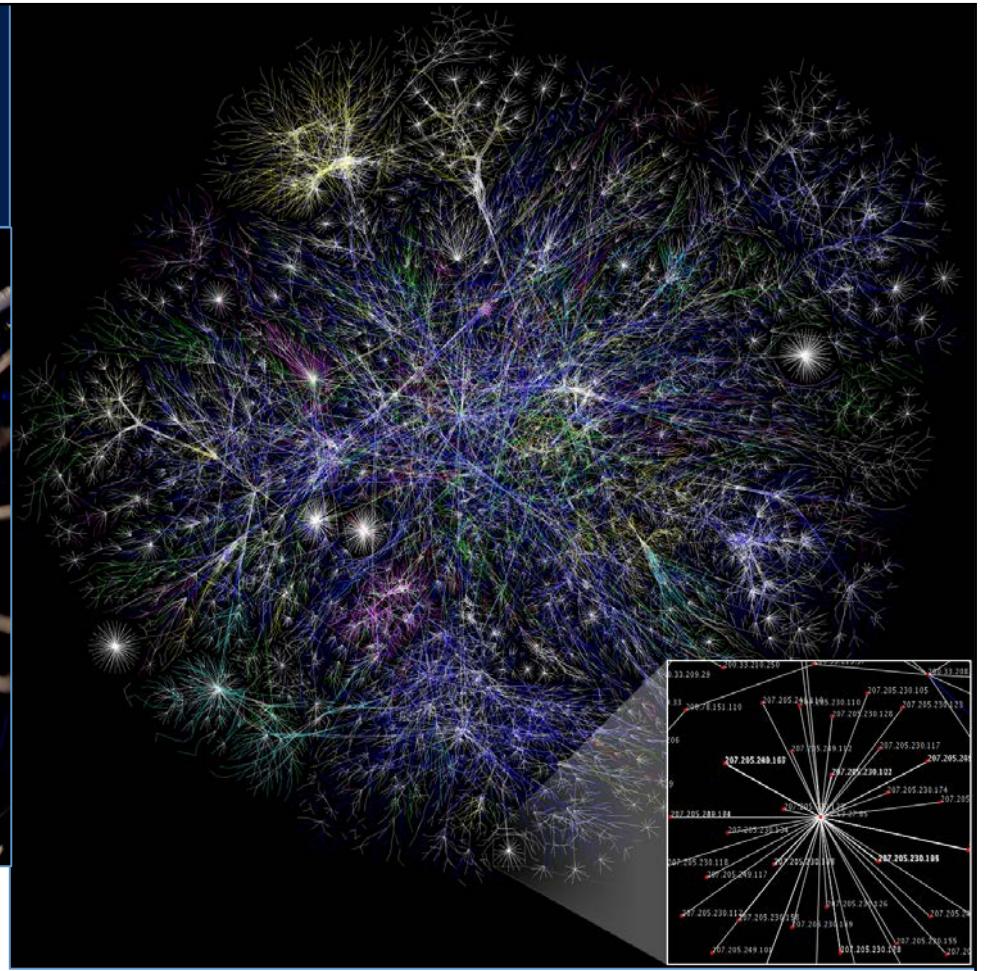


# Is It Alive?

# Wikipedia Servers

[Victor Grigas/Wikimedia Foundation CC BY-SA 3.0]

Lee, Berkeley



## View of the Internet

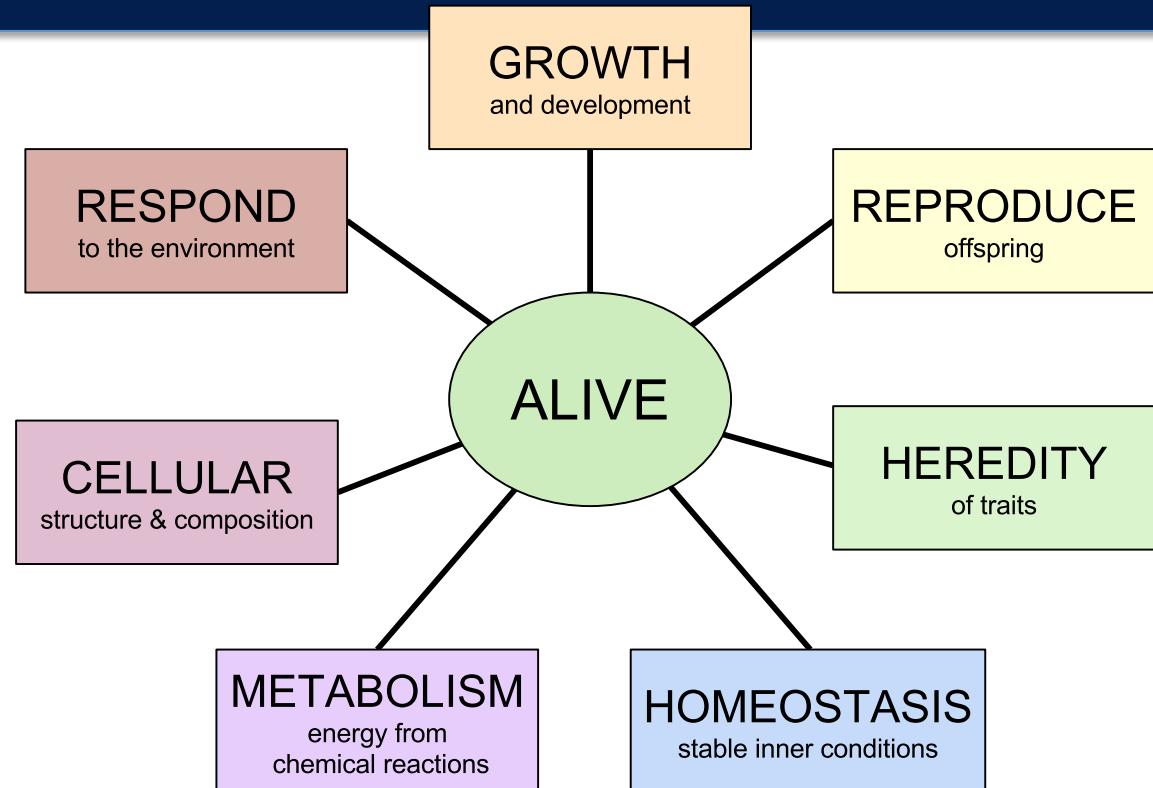
[The Opte Project, via Wikimedia Commons CC BY 2.5]



# What does it mean to be alive?

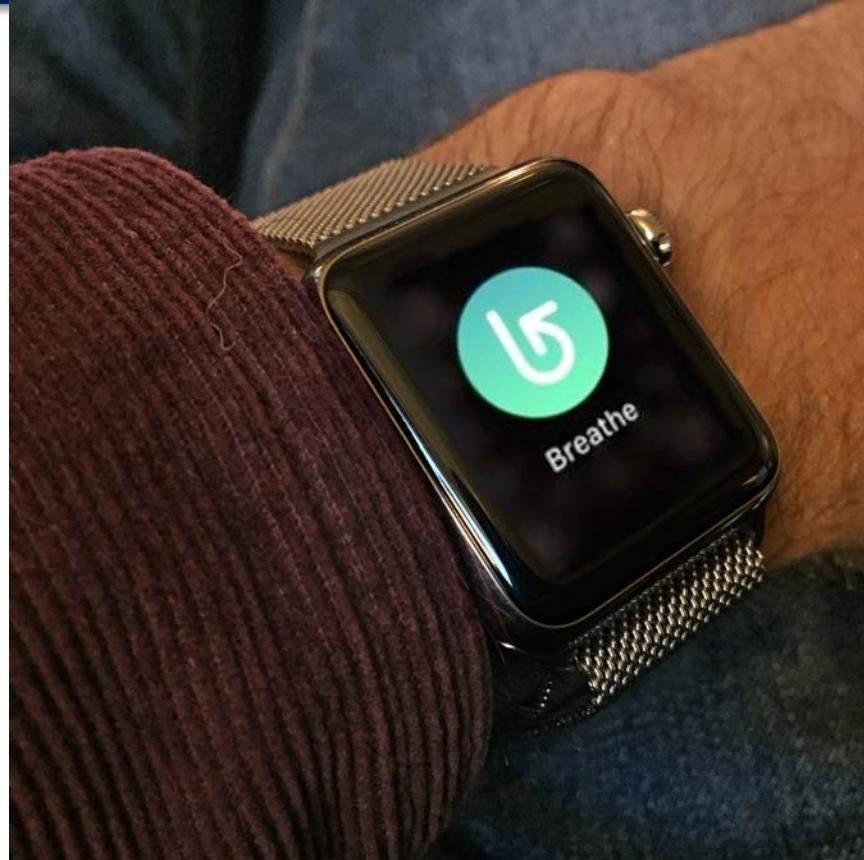
Wikipedia is arguably a “living digital being” (LDB, or “eldebee”).

It has all of these properties.





# Reproduction? Heredity? Mutation?



Lee, Berkeley

26



## Sterile Workers and a Queen Bee

[Photo by Max Pixel,  
released to public  
domain - CC0]

Lee, Berkeley





## So, Are They Alive?

This depends on what you mean by “alive,” but there is no doubt they share many features with biological beings.

And more importantly, their relationship with us is much like a biological symbiosis.

Lee, Berkeley

The  
Coevolution



The Entwined  
Futures of  
Humans and Machines  
Edward Ashford Lee

MIT Press, 2020



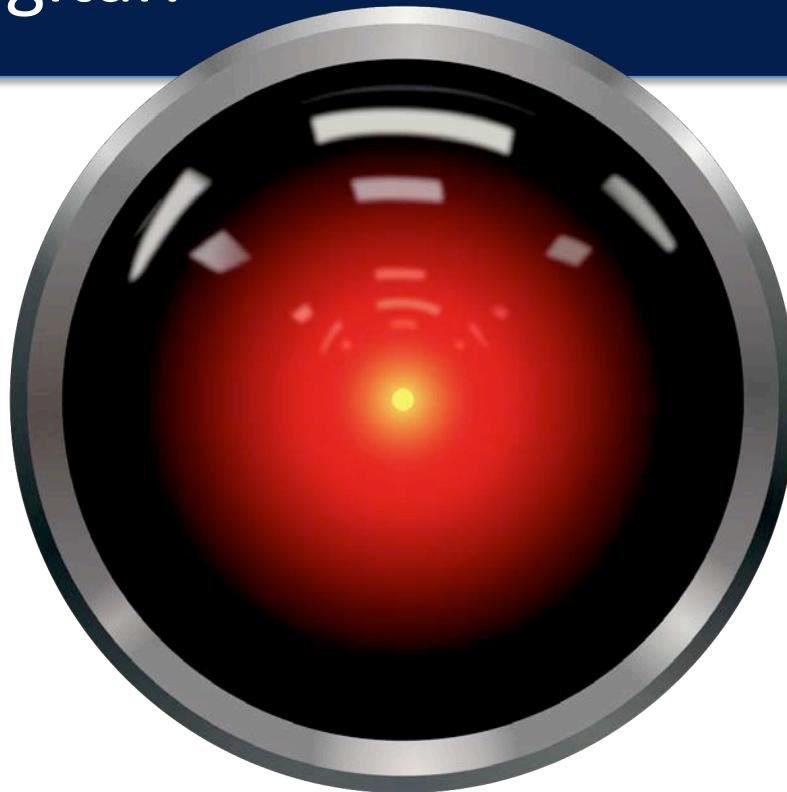
## Three Questions

1. Are we going to lose control of them?
2. Are they alive?
3. Are they going to match and exceed us?

Computers already exceed us in many dimensions.  
So the interesting question is: will they match us?



# Are We Digital?

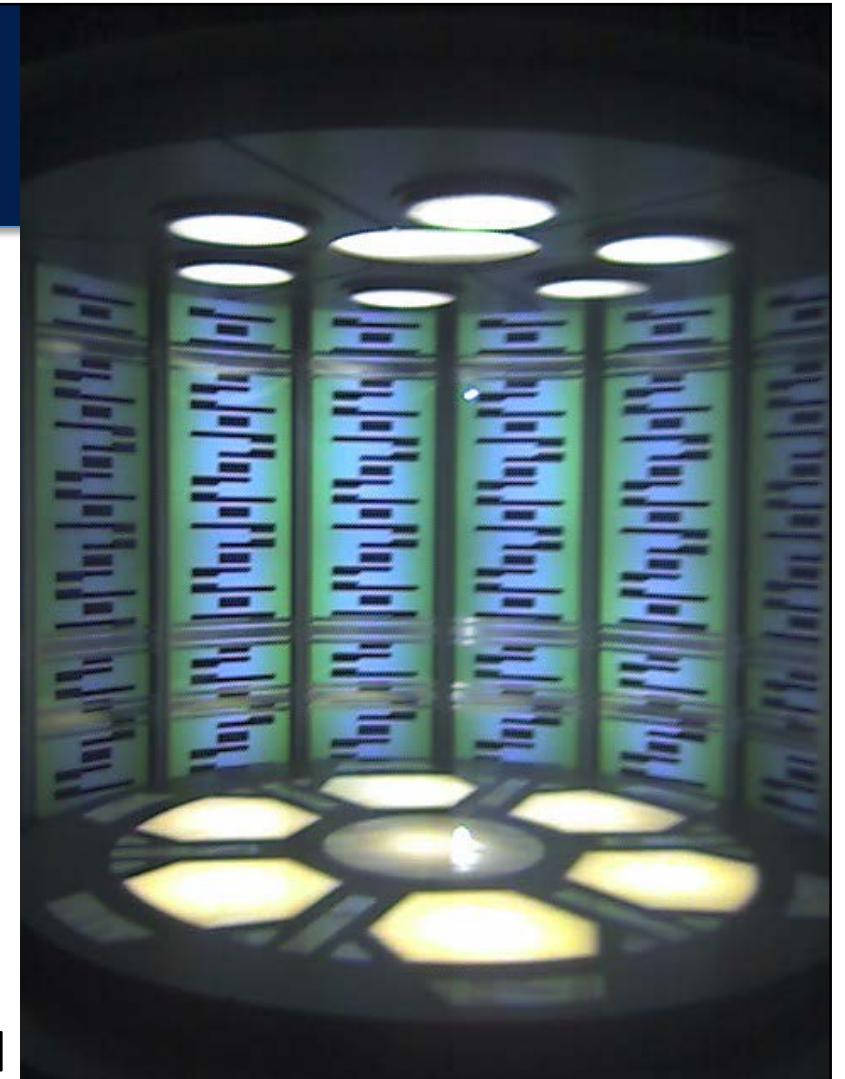


HAL, the computer in Stanley Kubrick's 1968 movie, *2001: A Space Odyssey*  
Lee, Berkeley



## Freeing the Mind From Matter

- Uploading?
- Teleportation?
- Are we really software and data?



Lee, Berkeley

Konrad Summers [CC BY-SA 2.0]



# Teleportation and Uploading

What happens to “I”?

- Is the reconstruction the same “I”?
  - How can we tell?
- What if the original is not destroyed?
  - Two “I”s?
- What if a backup copy is later instantiated?
  - Two “I”s of different ages?



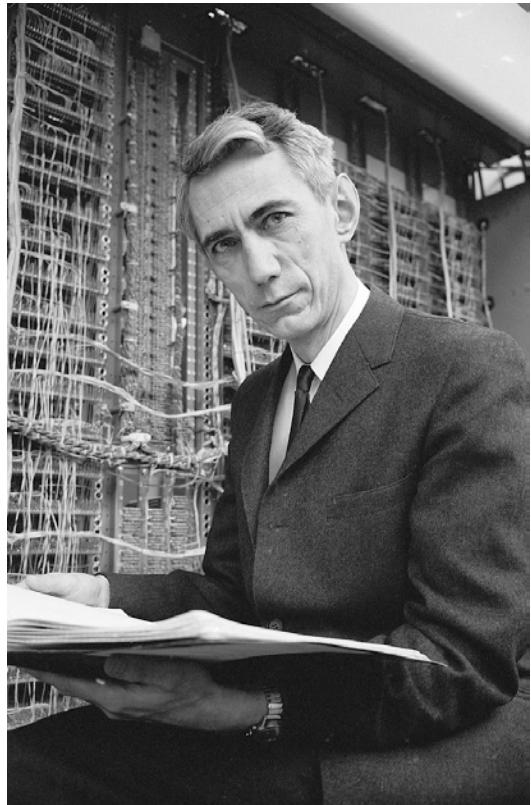
## The Sense of Self Per Three Philosophers

What happens to “I”?

- Derek Parfit:
  - The notion of “I” makes no sense.
- Daniel Dennett:
  - “I” is a fiction, an illusion, a social construction.
- Douglas Hofstadter
  - “I” can be in two places at once.



## A Simpler Answer: “I” Is Not Digital



Shannon showed in 1948 a noisy channel can, in principle, perfectly convey a finite number of bits (the “channel capacity”).

The converse is even more important: A noisy channel *cannot* convey *more* than a finite number of bits.

Claude Shannon

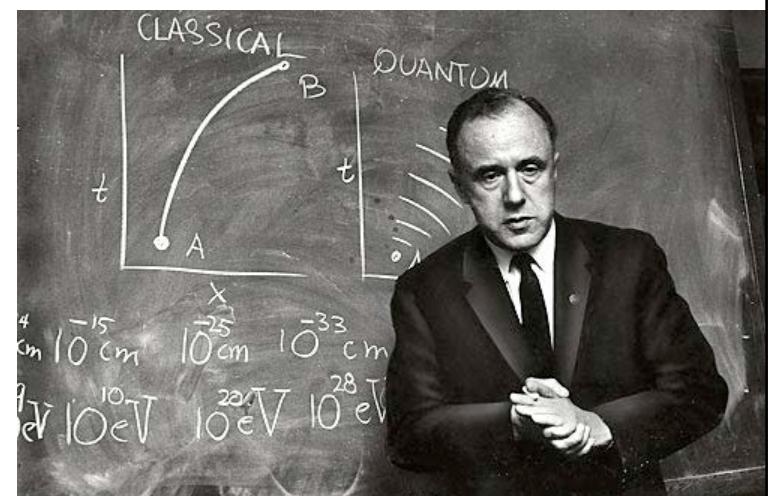


# Or Maybe *Everything* is Digital?

Variants of the “Digital Physics” hypothesis:

1. The number of possible states of a physical system is finite.
2. Physical processes are digital and algorithmic.
3. Every physical process is a Turing computation.
4. The physical world is a computer.
5. The physical world is a simulation.

John Archibald Wheeler  
“It from bit”



*These theses are not falsifiable by experiment,  
and therefore not scientific according  
to the philosophy of Karl Popper.*

Lee, Berkeley



## *Dataism* is a Faith not a Scientific Principle



I borrowed the term “dataism” from Yuval Noah Harari.

[Photo By Daniel Naber  
-CC BY-SA 4.0]

Lee, Berkeley

Yuval Noah Harari  
*New York Times* Bestselling  
Author of *Sapiens*



Homo  
Deus  
A Brief History  
of Tomorrow



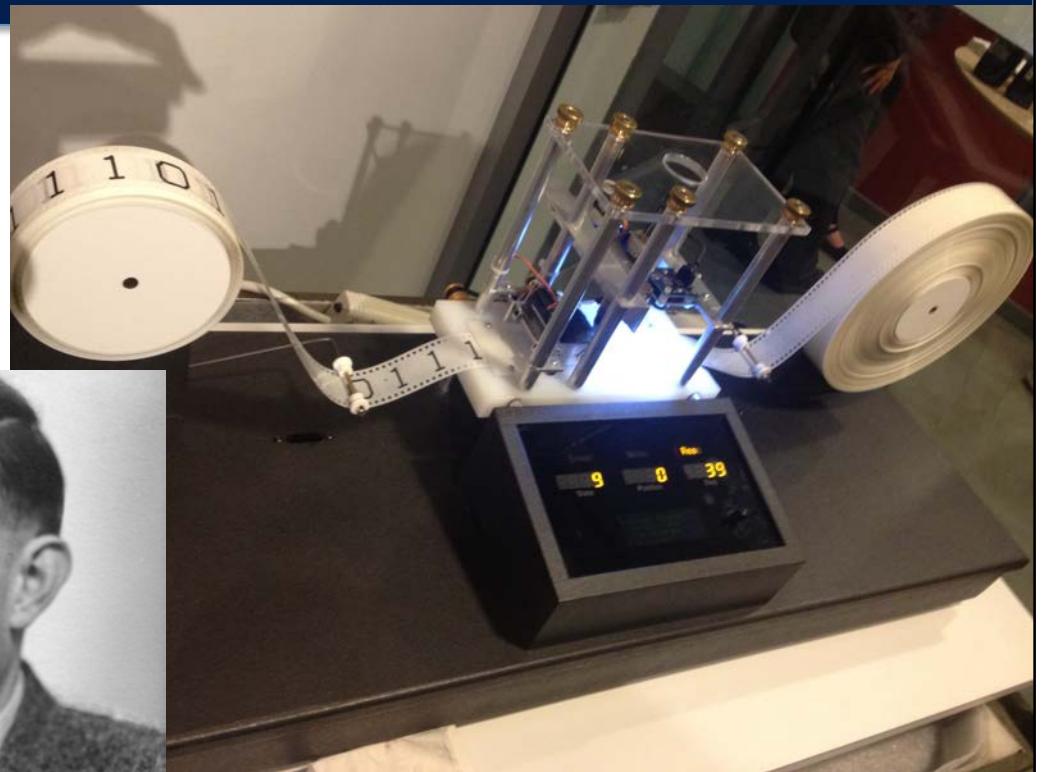
# The “Universal Machine” Fallacy

Turing machines:

- Algorithmic
- Digital
- Terminating

Alan Turing

Lee, Berkeley



Machine designed by Mike Davey  
[Photo by GabrielF, CC BY-SA 3.0]



## No Universal Machine Has Yet Been Invented



Kurt Gödel

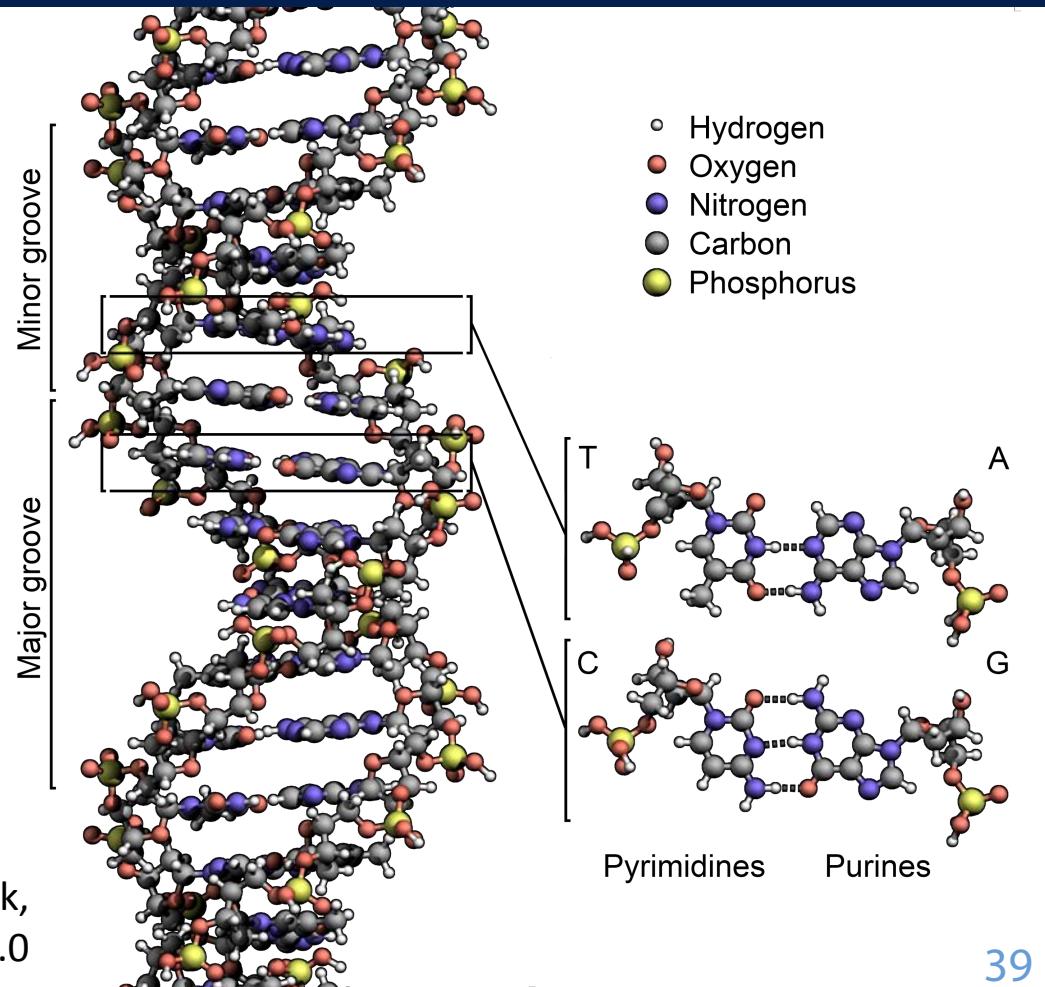
If one is ever invented, it will not be, at its essence, a discrete, algorithmic, terminating process.



# The DNA Fallacy

Every human alive today is the endpoint of continuous, unbroken, biological process dating back about four billion years.

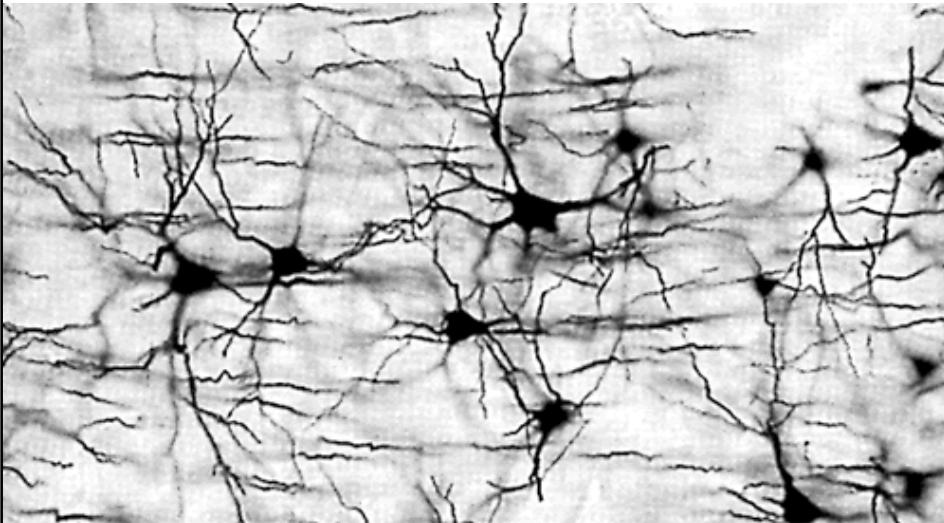
By Zephyris - Own work,  
CC BY-SA 3.0





# The Connectomics Fallacy

- Neurons fire discretely. (McCulloch and Pitts, 1940s)
- Neurons combine to realize logic functions.
- Logic functions can be realized on other hardware (Putnam, 1960s).
- Connections will reveal brain function (Lichtman, 2000s).



Camillo Golgi's method  
(1870s) gives a misleading  
picture of the brain.



# Connectomics: A More Complete Picture of the Brain

Can we understand brain function by studying the wiring diagram,  
even in principle?



iBiology.org

Jeff Lichtman,  
Harvard



If Cognition is not a Digital,  
Algorithmic Process, then...

“Your mind is entirely your own.”



And we have not yet  
invented the technology  
to make cognitive AIs.



# Digital Humanism

- A call to action
- A rejection of naïve approaches
- A call to a multidisciplinary approach
  - Humanists
  - Scientists
  - Politicians
  - Technologists
- A call for humility

Lee, Berkeley



Hannes Werthner, lead author of the Vienna Manifesto on Digital Humanism.

**DIGHUM** MANIFESTO BACKGROUND COMMENTS SUPPORTERS

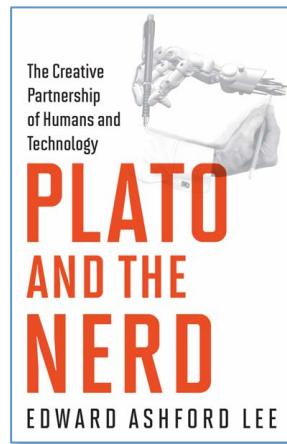
<https://www.informatik.tuwien.ac.at/dighum>

**Vienna Manifesto on Digital Humanism**  
Vienna, May 2019  
"The system is failing" – stated by the founder of the Web, Tim Berners-Lee – emphasizes that while digitalization opens unprecedented opportunities, it also raises serious concerns: the monopolization of the Web, the rise of extremist opinions and behavior orchestrated by social media, the formation of filter bubbles and echo chambers as islands of disjoint truths; the loss of privacy, and the spread of digital surveillance. Digital technologies are disrupting societies and questioning our understanding of what it means to be human. The stakes are high and the challenge of building a just and democratic society with humans at the center of technological progress needs to be addressed with determination as well as scientific ingenuity. Technological innovation demands social innovation, and social innovation requires broad societal engagement.

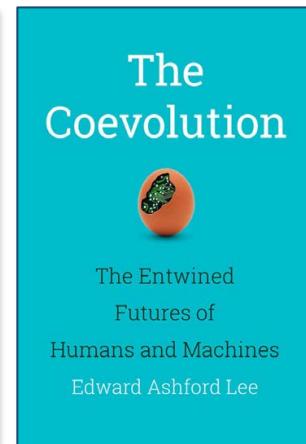


## Conclusion

We *nudge* rather than *control* technology development, and we change as technology changes. Only with a deeper understanding of these coevolutionary processes can we have any hope of effective policies that ensure that technology serves humanity.



MIT Press, 2017



MIT Press, 2020

Lee, Berkeley