STEAM to the Future: The 4th Industrial Revolution is Coming

Sylvia Martinez
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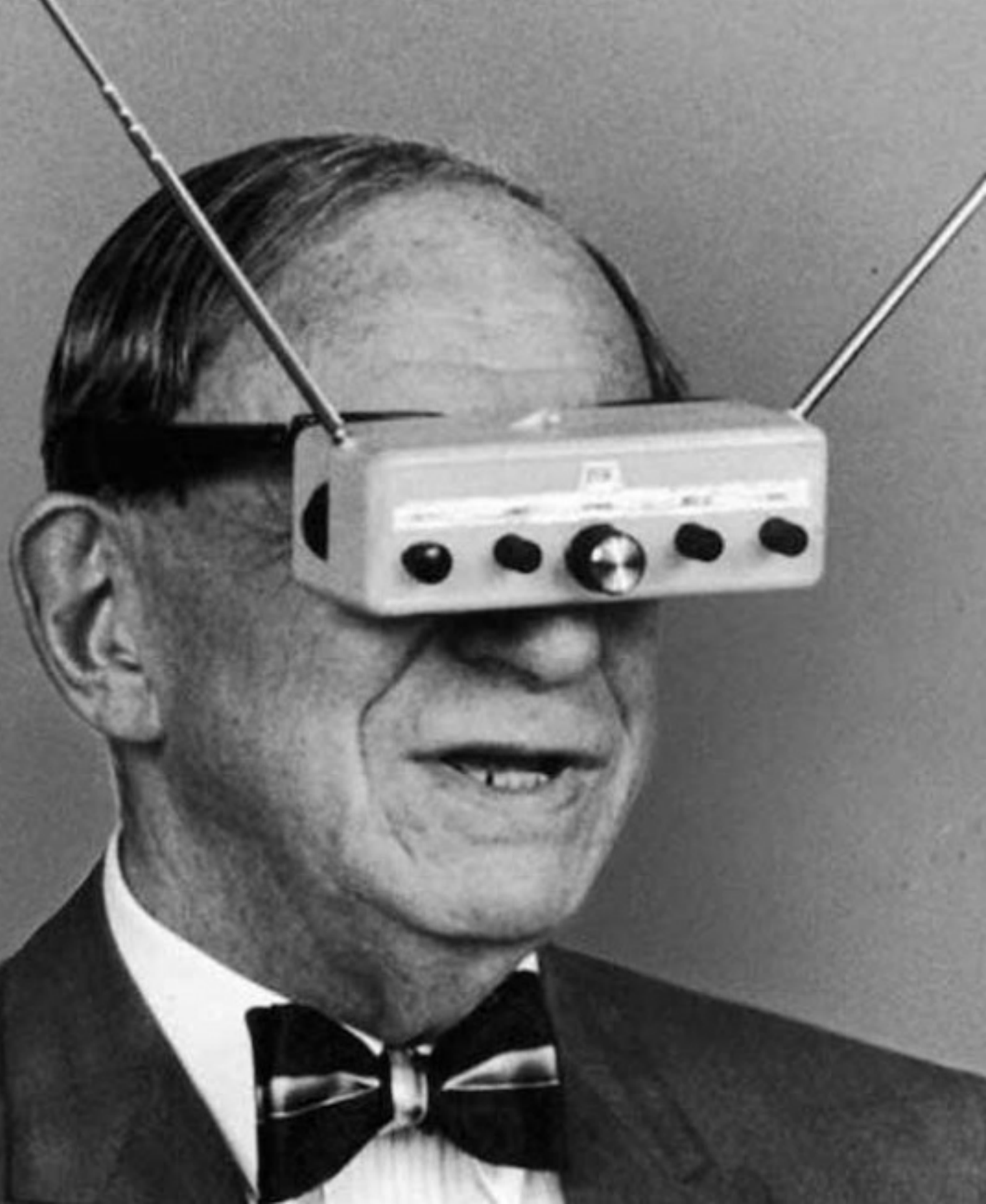
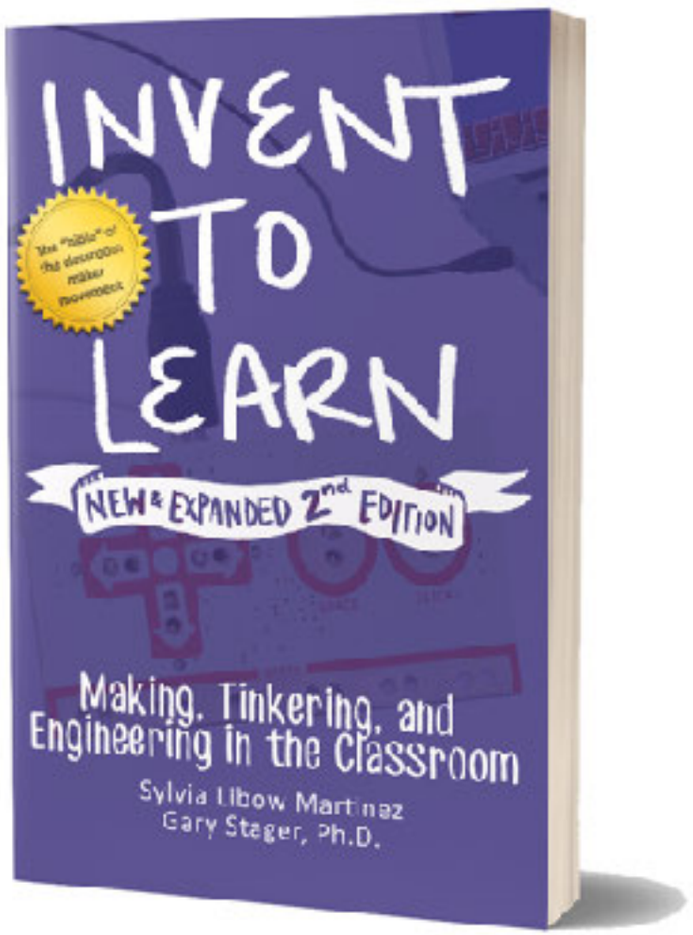
Twitter: @smartinez
sylviamartinez.com



Invent To Learn:

Making, Tinkering, and Engineering in the Classroom

www.InventToLearn.com



- Maker tools, materials, & tech
- Tinkering mindset
- Engineering design
- How to make the case for "making" in the classroom

robotics e-textiles 3D printing micro:bit Scratch Raspberry Pi programming electronics sensors laser cutters STEM/STEAM

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1969 - 2019 - 2069

A story of exponential growth

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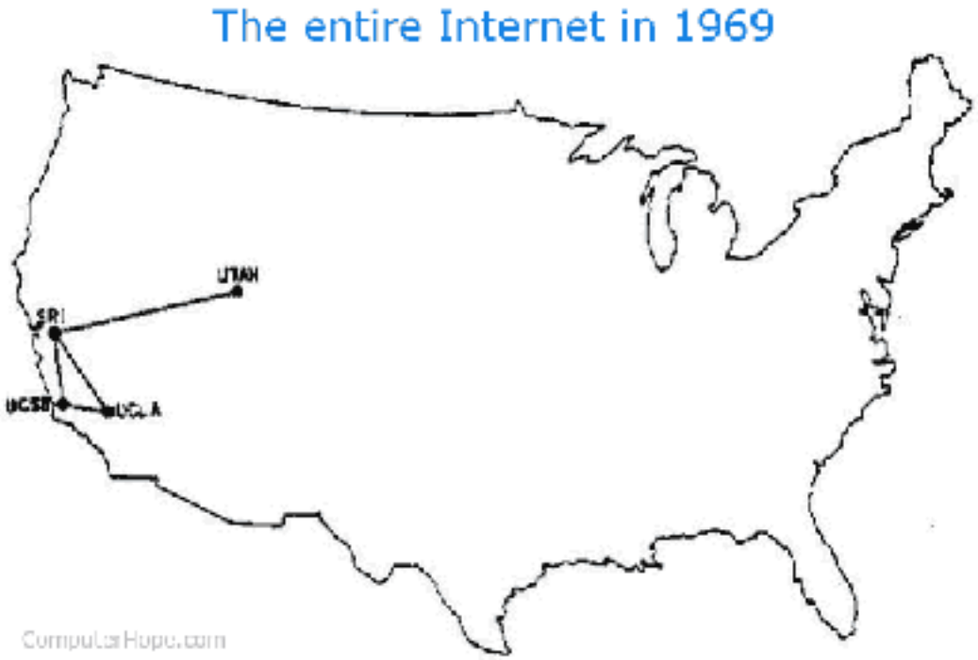
Nova minicomputer
$8,000
32KB memory

First floppy drive
80KB

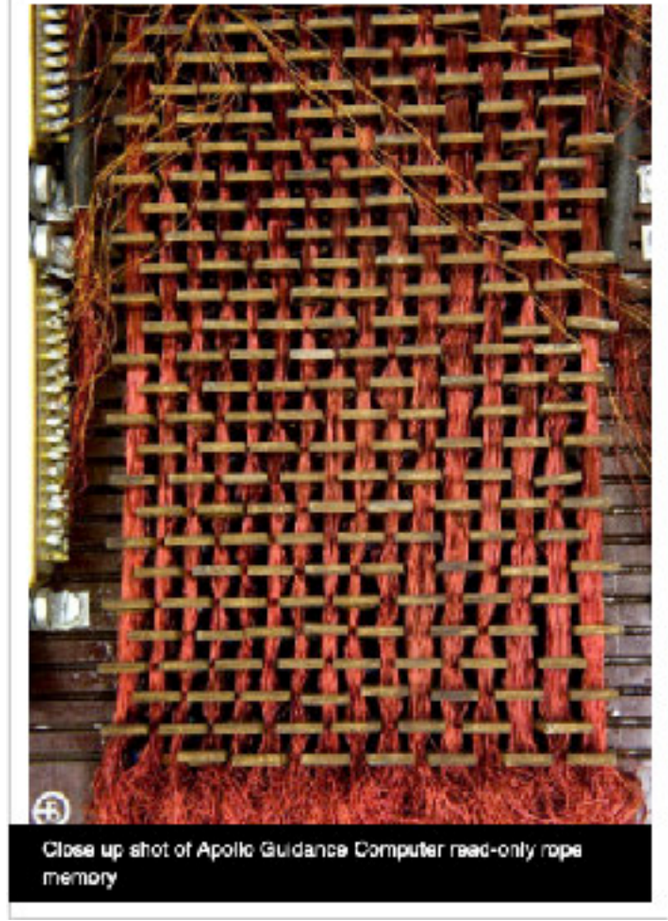
Computational technology

Communication device



Navigation equipment

Video game
Spacewar
PDP-1



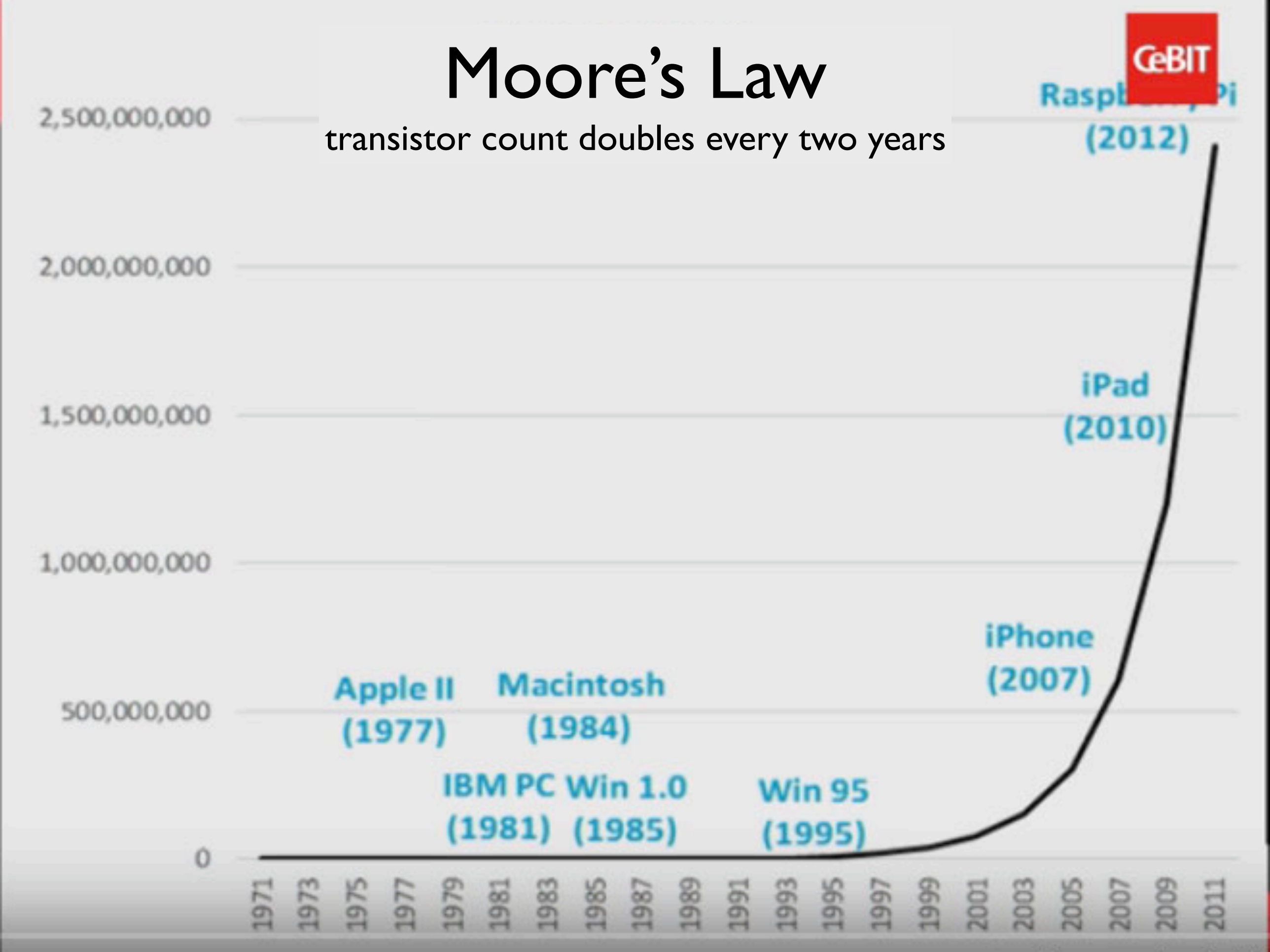
Apollo 11 Guidance Computer
72kb rope memory

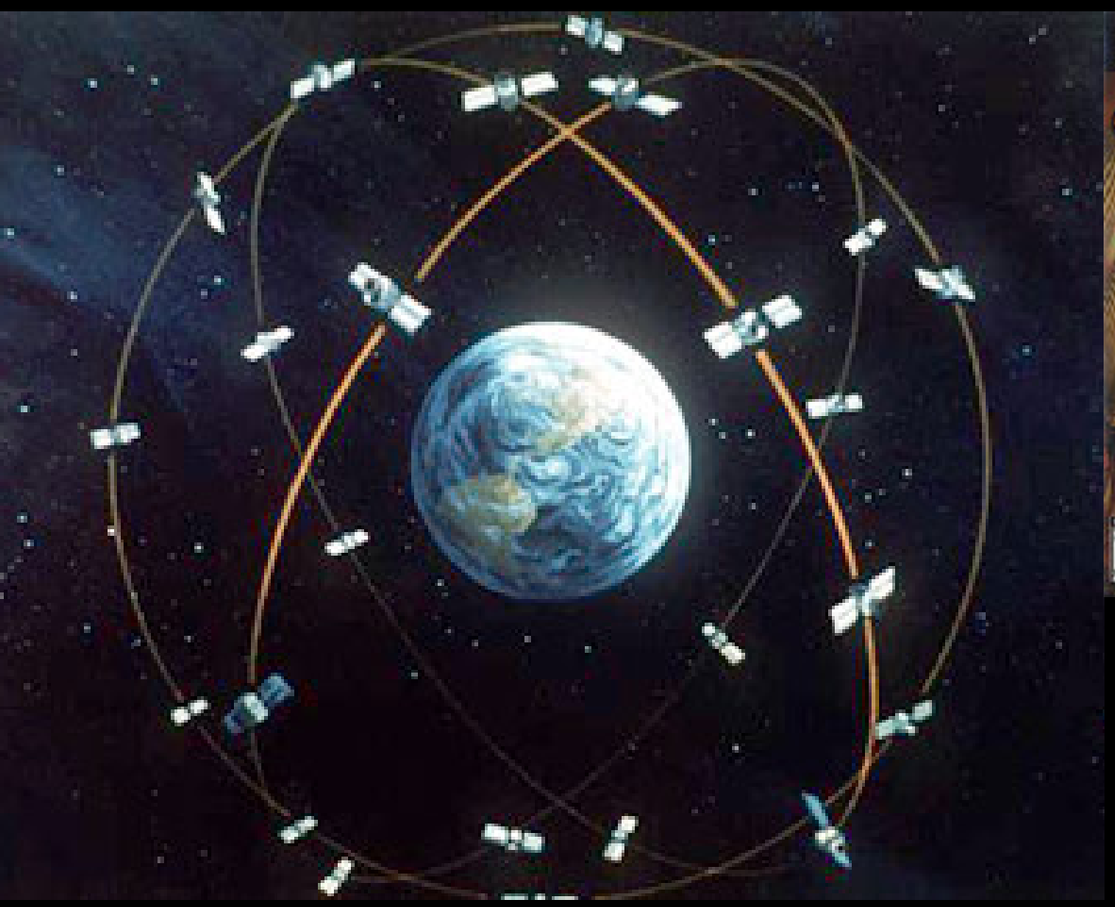
The worst!

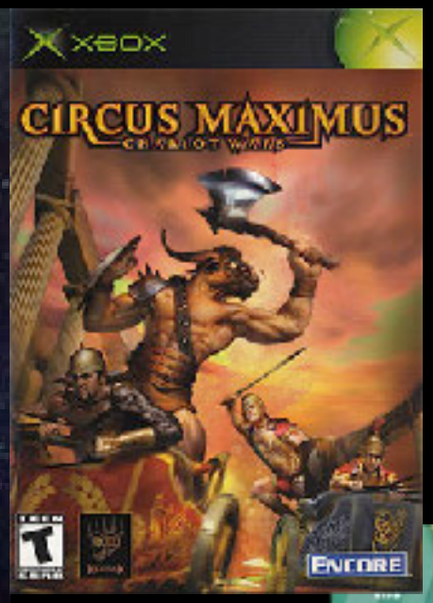
sylviamartinez.com

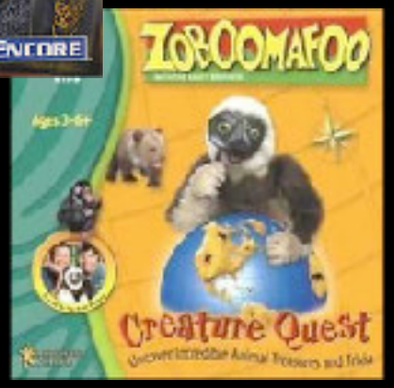
Moore's Law

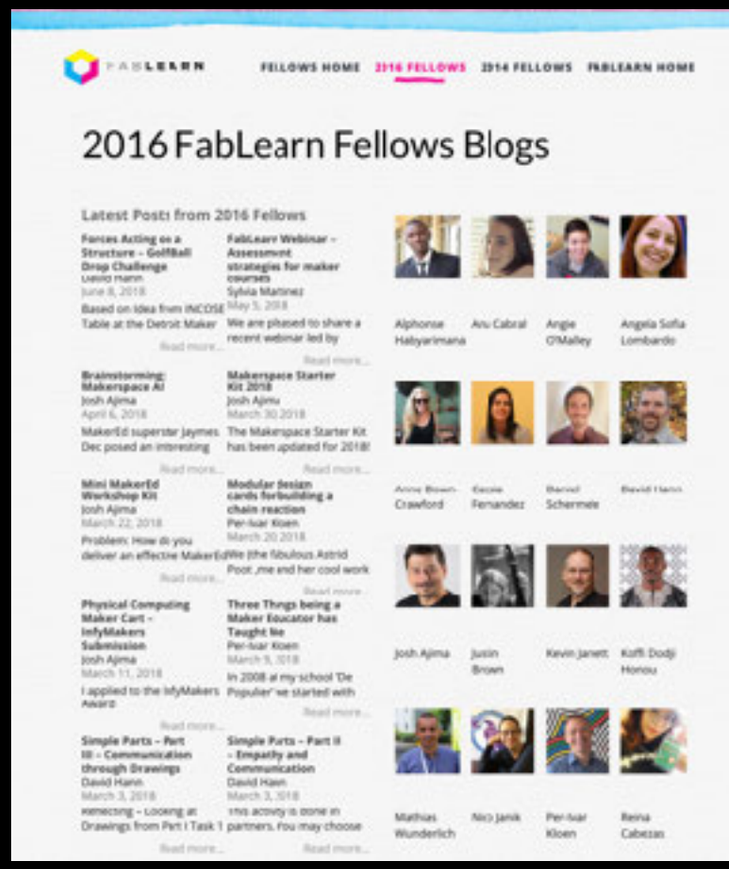
transistor count doubles every two years

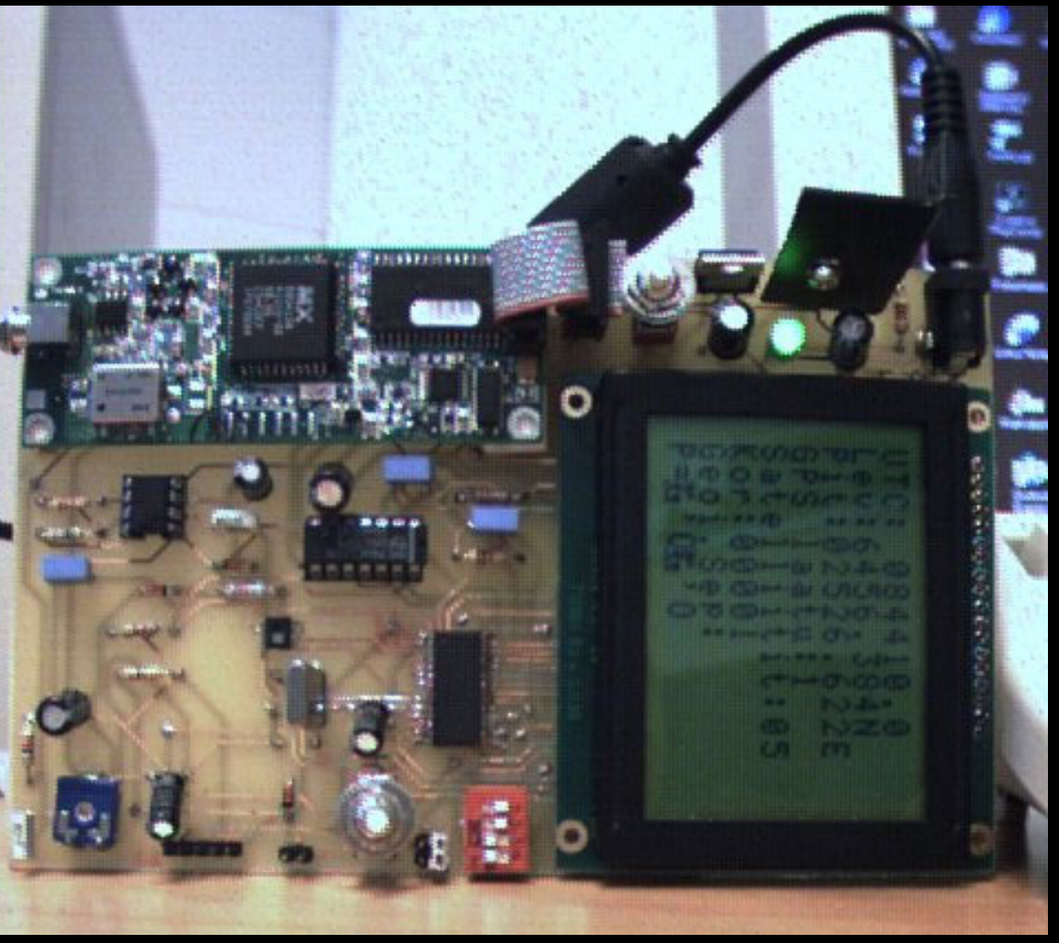


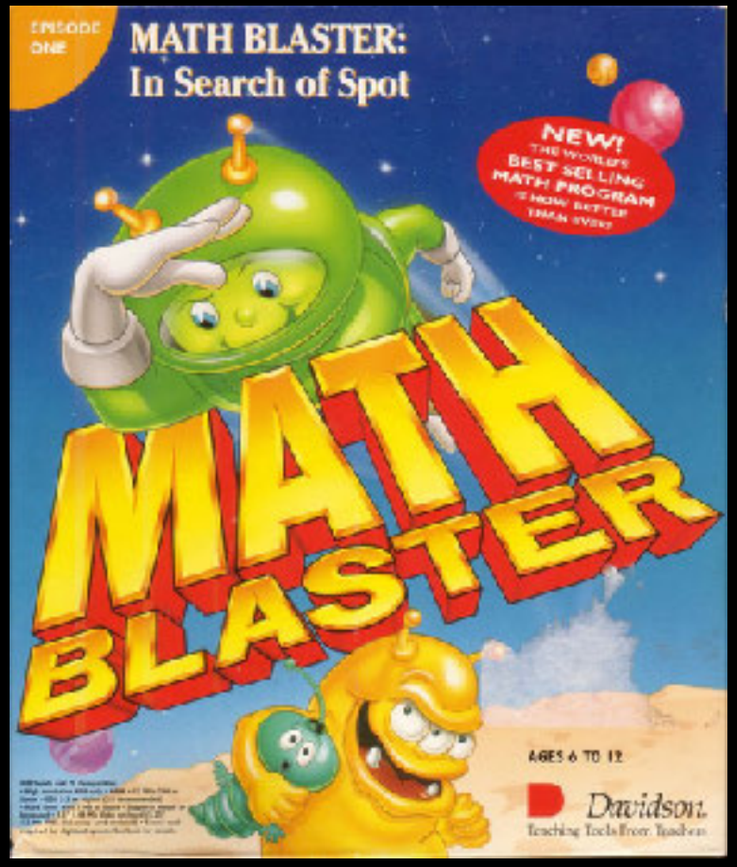



XBOX
CIRCUS MAXIMUS
CHARIOT WARS
ENCORE

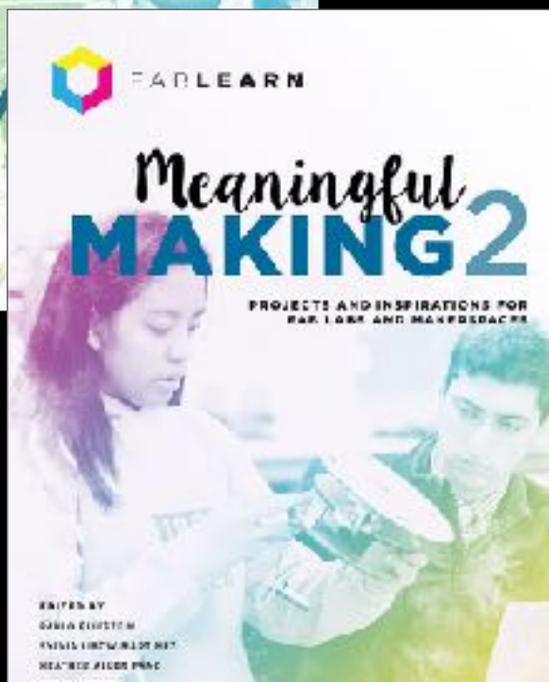

ZOOMAFOO
Creature Quest


FABLEARN
FELLOWS HOME
2016 FELLOWS
2014 FELLOWS
FABLEARN HOME
2016 FabLearn Fellows Blogs
Latest Posts from 2016 Fellows
Forces Acting on a Structure – Golfball Drop Challenge
FabLearn Webinar – Assessment strategies for maker courses
Brainstorming: Makerspace AI
Makerspace Starter Kit 2018
Mini MakerEd Workshop Kit
Modular design cards forbuilding a chain reaction
Physical Computing Maker Cart – InfyMakers Submission
Three Things being a Maker Educator has Taught Me
Simple Parts – Part III – Communication through Drawings
Simple Parts – Part II – Empathy and Communication
Alphonse Habyarimana
Anu Cabral
Angie O'Malley
Angela Sofia Lombardo
Josh Ajima
Justin Brown
Kevin Jarrett
Kofi Dodji Honou
Mathias Wunderlich
Nici Janik
Per-Ivar Kloen
Reina Cabezas




EPISODE ONE
MATH BLASTER:
In Search of Spot
NEW!
MATH BLASTER
AGES 6 TO 12
Davidson
Teaching Tools From Teachers

FABLEARN


FABLEARN
Meaningful MAKING 2
PROJECTS AND INSPIRATIONS FOR FAB LABS AND MAKERSPACES

Navigating the next industrial revolution

WORLD ECONOMIC FORUM
COMMITTED TO IMPROVING THE STATE OF THE WORLD

Revolution	Year	Information
1	1784	Steam, water, mechanical production equipment
2	1870	Division of labour, electricity, mass production
3	1969	Electronics, IT, automated production
4	?	Cyber-physical systems

"Blurring the lines between physical, digital, and biological spheres."

https://en.wikipedia.org/wiki/Fourth_Industrial_Revolution

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10 STEAM Futures

1. Biomaking
2. The End of Moore's Law
3. Synthetic Biology
4. Augmented and Virtual Reality
5. Robots
6. Artificial Intelligence
7. Small Solutions for Big Problems
8. Algorithms & Ethics
9. Fabrication
10. Don't forget the M (ath)

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1 - Biomaking

Replace petrochemicals, reduce pollution, trash, and environmental damage

Fungus-based materials

Bioplastics

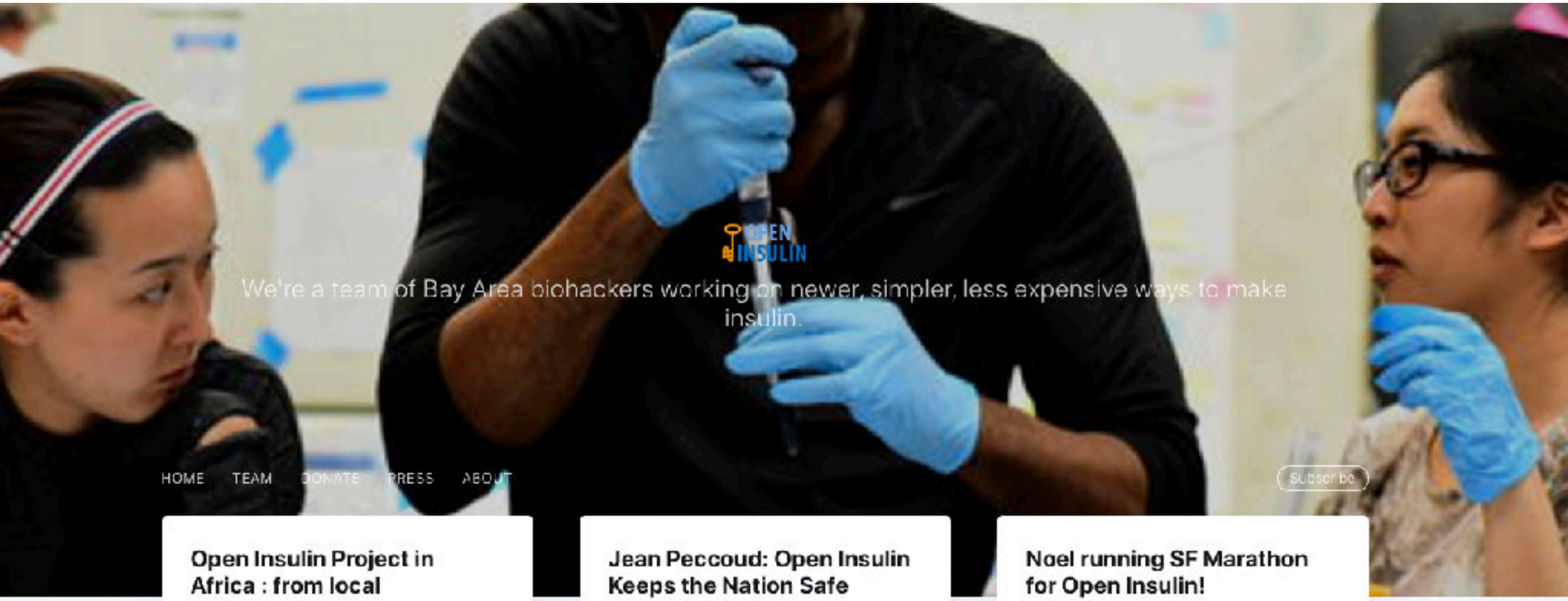
Democratizing biology

Fabrication using bone growth algorithms

Self-healing concrete

Colonies of Bacillus bacteria remain dormant until exposed to rainwater. Once a crack forms, the bacteria releases a hard substance, calcium lactate (a compound found in milk) to seal the gap.
Henk Jonkers Delft Technical University in the Netherlands

The open insulin project



Open Insulin Project in Africa : from local communities to the lab

Contact With the Open Insulin Project In September 2017, I gave a talk at the Biosummit (organised by MIT-Medialab) on the topic : Biohacking in Africa : a tool for justice, empowerment and development. During

THOMAS MBOA

Jean Peccoud: Open Insulin Keeps the Nation Safe

The following is a guest post by Jean Peccoud, Department of Chemical & Biological Engineering, Colorado State University. Jean hosted Anthony's talk at CSU in September of 2016, and remains engaged in the

ANTHONY DI FRANCO

Noel running SF Marathon for Open Insulin!

Hi all, our computational protein modeling expert Noel is running the San Francisco marathon this weekend to raise funds for the project! He's made a mini-documentary about the project as well which you

ANTHONY DI FRANCO

OPEN INSULIN

Onwards and Upwards in

Summer update

Elena Amato creates sustainable cosmetics packaging from bacteria

Natashah Hitti | 28 February 2019 | Leave a comment

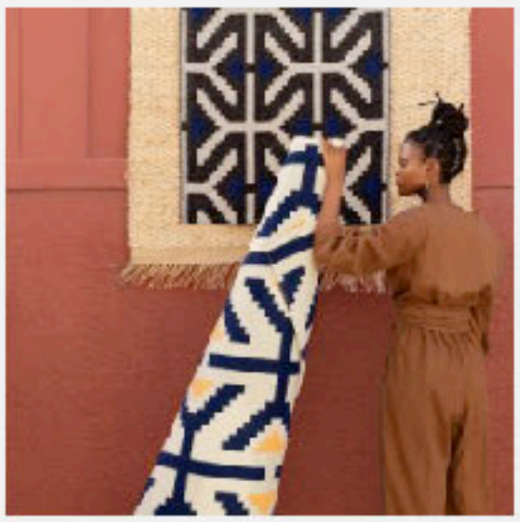
Guatemalan designer Elena Amato has created sheets of bacterial cellulose with paper-like qualities as a sustainable alternative to the plastic packaging used in personal care products.

The bacterial cellulose sheets were developed using a mixture of water and a bacteria and yeast (scoby) culture, which is blended together before being spread out on a flat,

ds" in a new tab

Top design stories

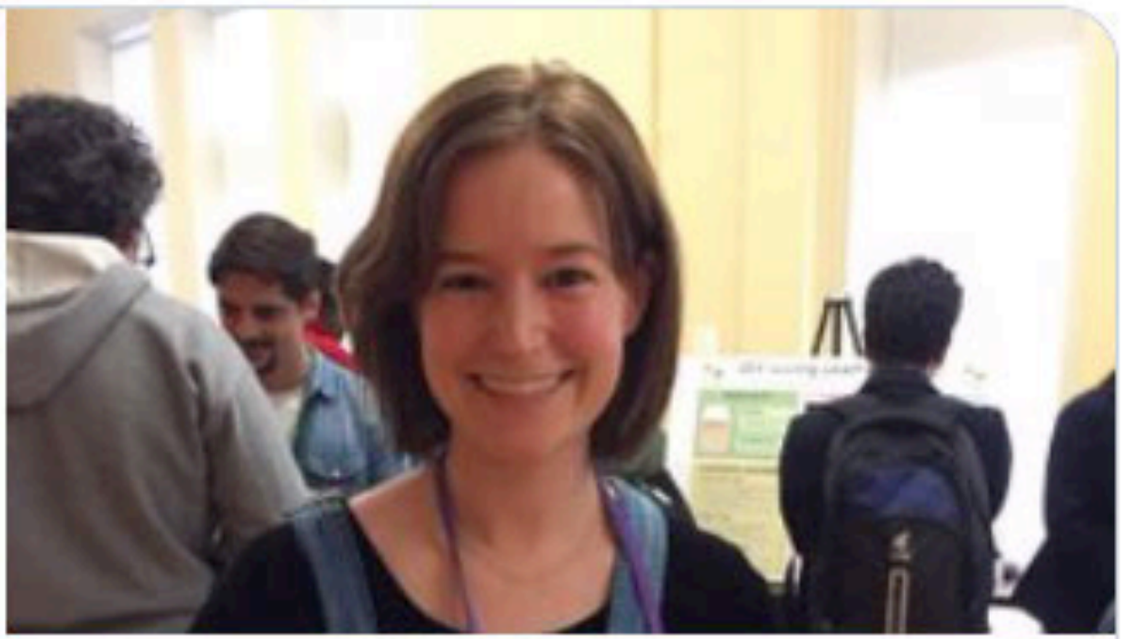
Most popular | Most recent

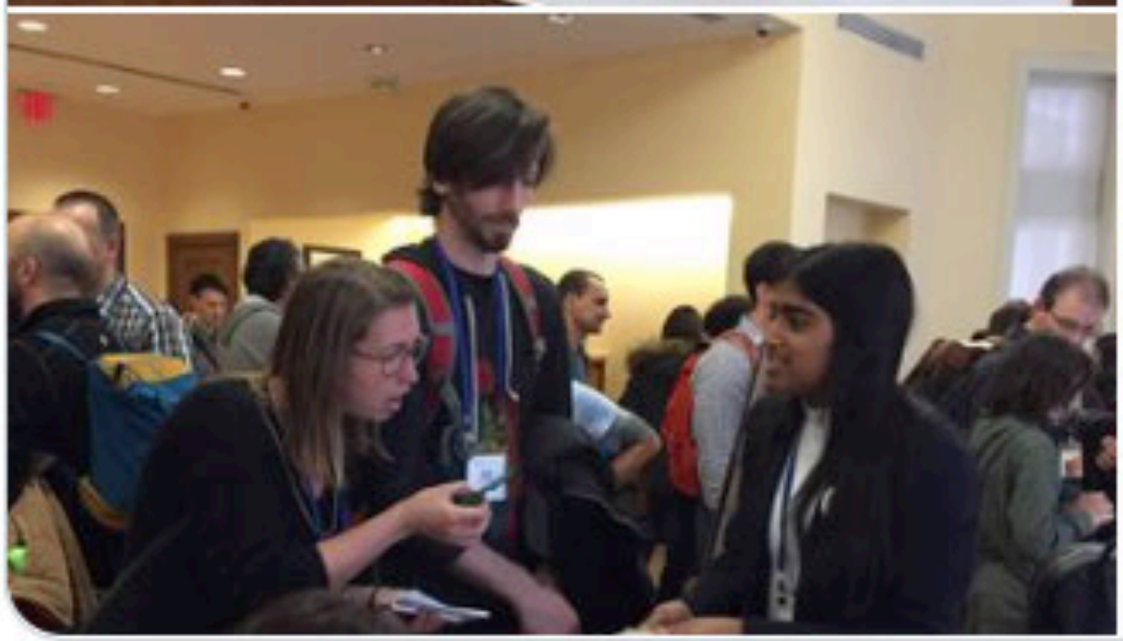


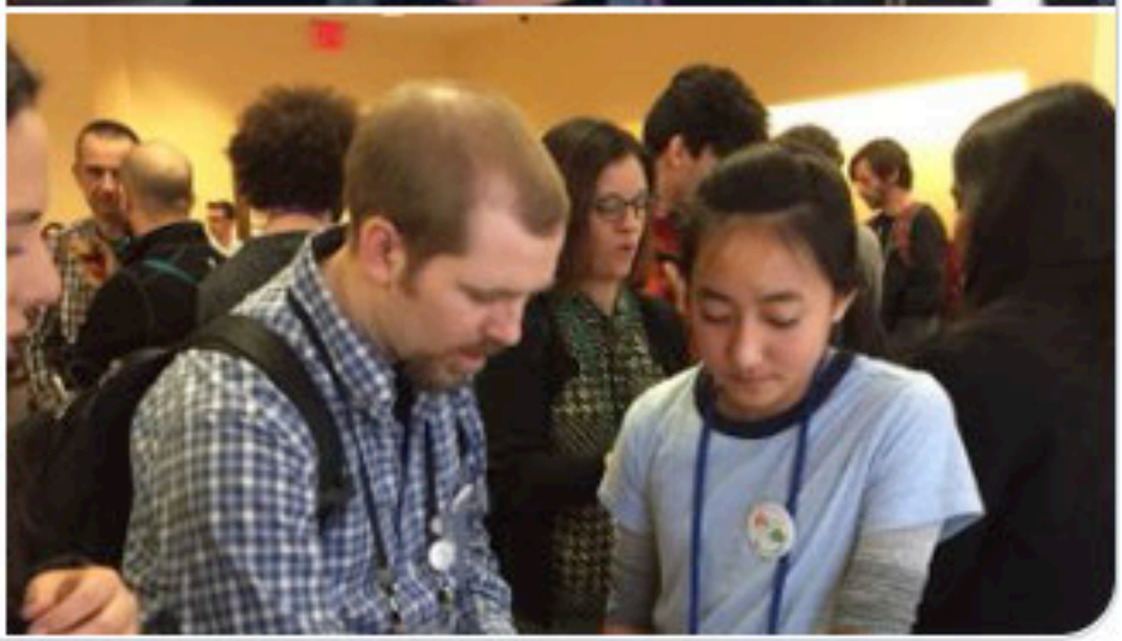
1 IKEA and Design Indaba launch Överallt furniture by African designers

Corinne Okada Takara @CorinneTakara · Mar 26

Nest Makerspace team wondering where their kombucha leather wings are around the globe now. If you got one these at #FabLearn, could you share a photo of your wings & where you are? Thanks @titojankowski for this idea of a sort of Flat Stanley sharing! @Biodesigned #biotinkering







Corinne Okada Takara Retweeted

Caitlin Nealon, PhD @ BDC @benchadjacent · Jun 20

The GIY Biobuddies gave an awesome presentation of their biodesign toy kits @Biodesigned. It's been amazing to watch these young women grow their project this year! #bdcsummit2019

5 14

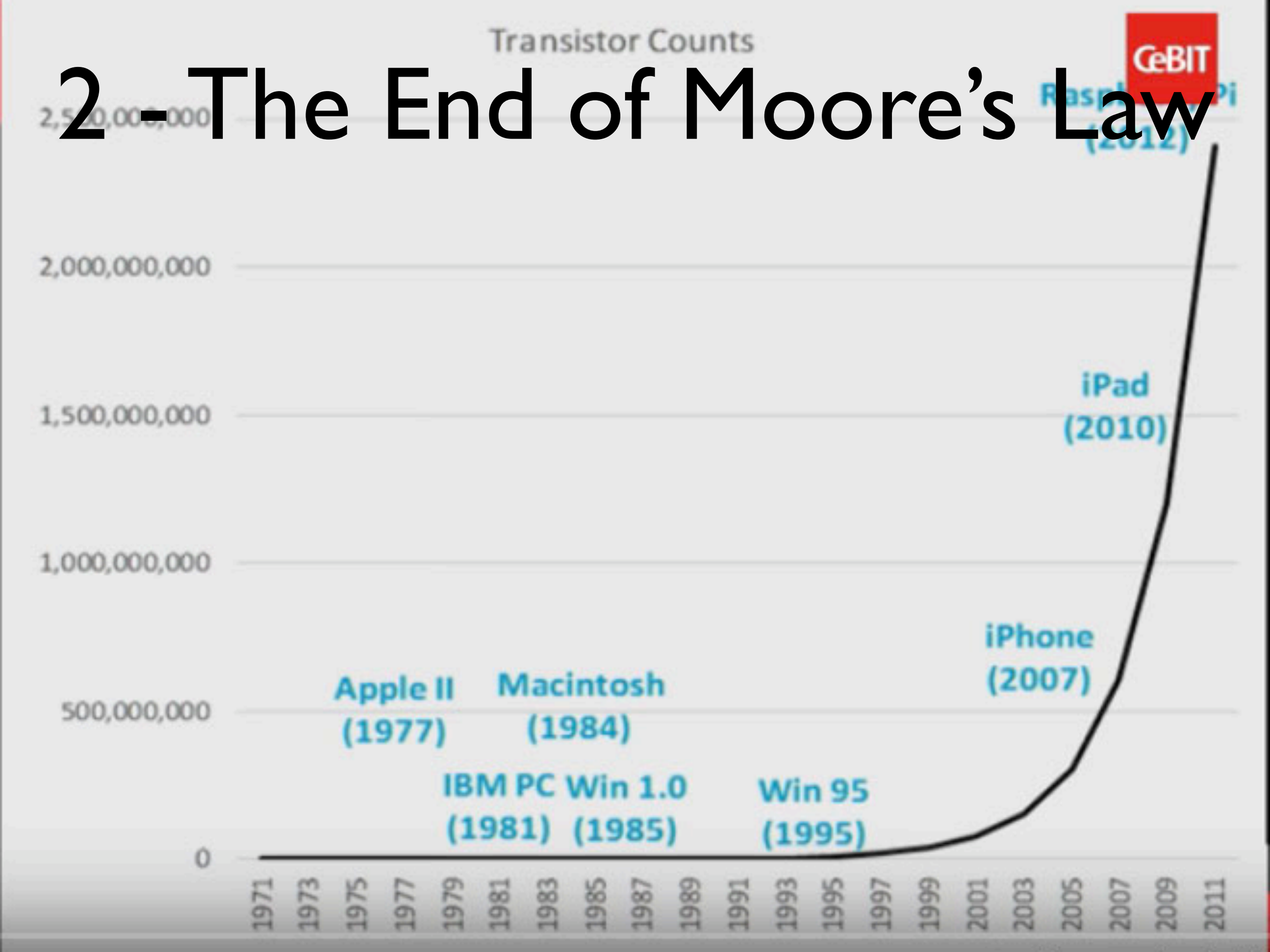
RESOURCES SCHOOLS SPONSORS

LEARN. CREATE. GROW.

Biodesign Challenge

biodesignchallenge.org

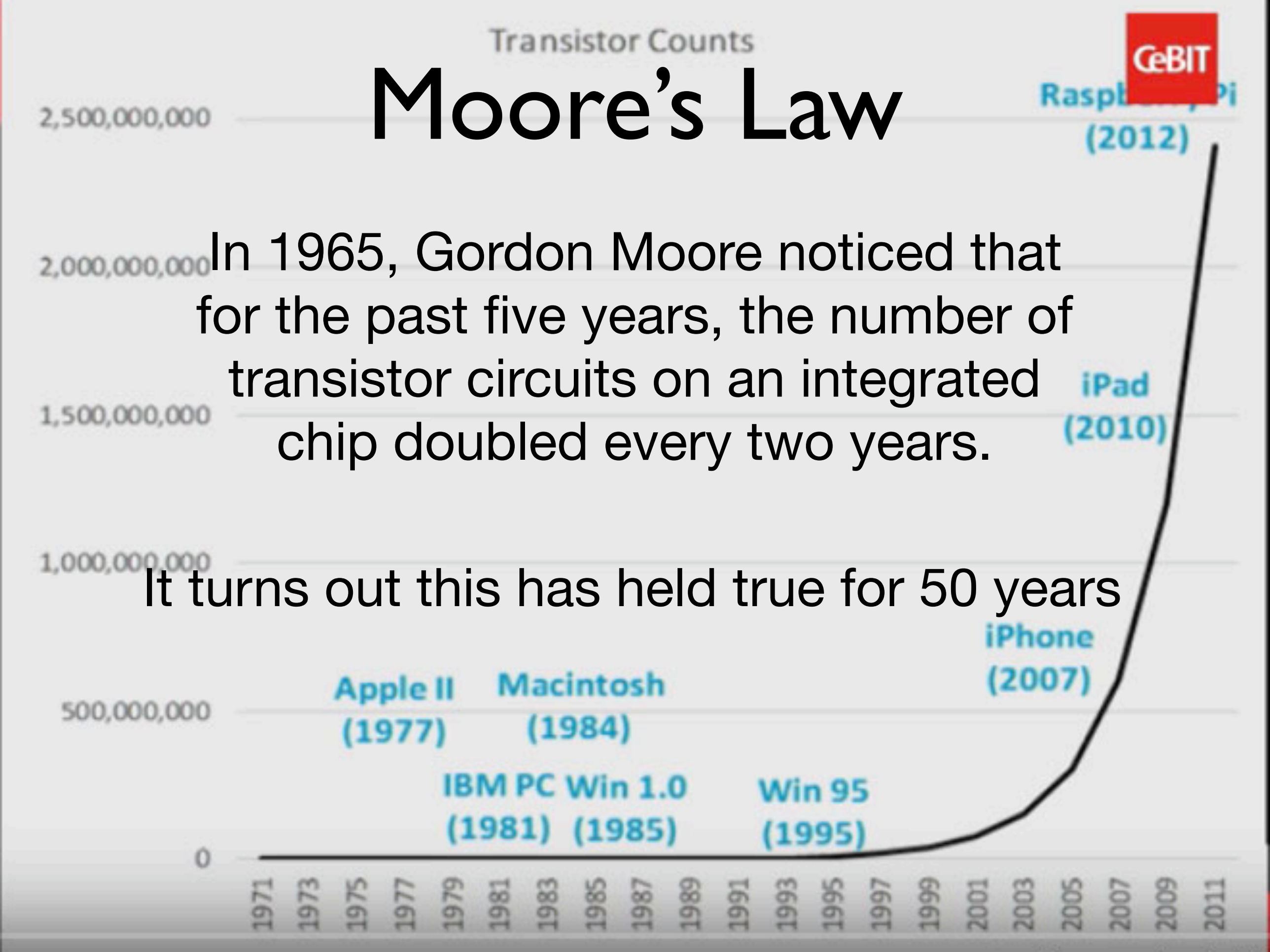
2 - The End of Moore's Law

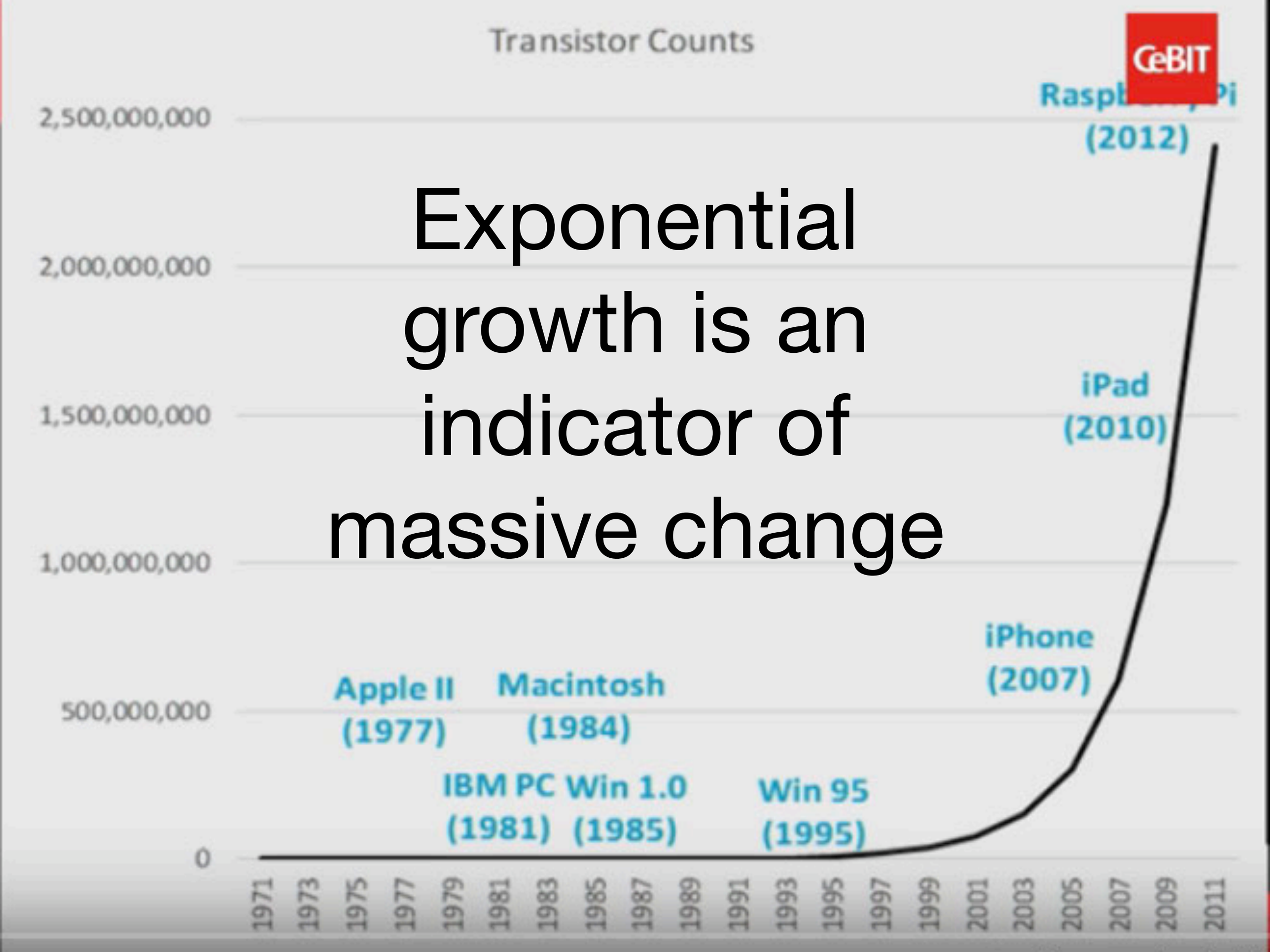


Moore's Law

In 1965, Gordon Moore noticed that for the past five years, the number of transistor circuits on an integrated chip doubled every two years.

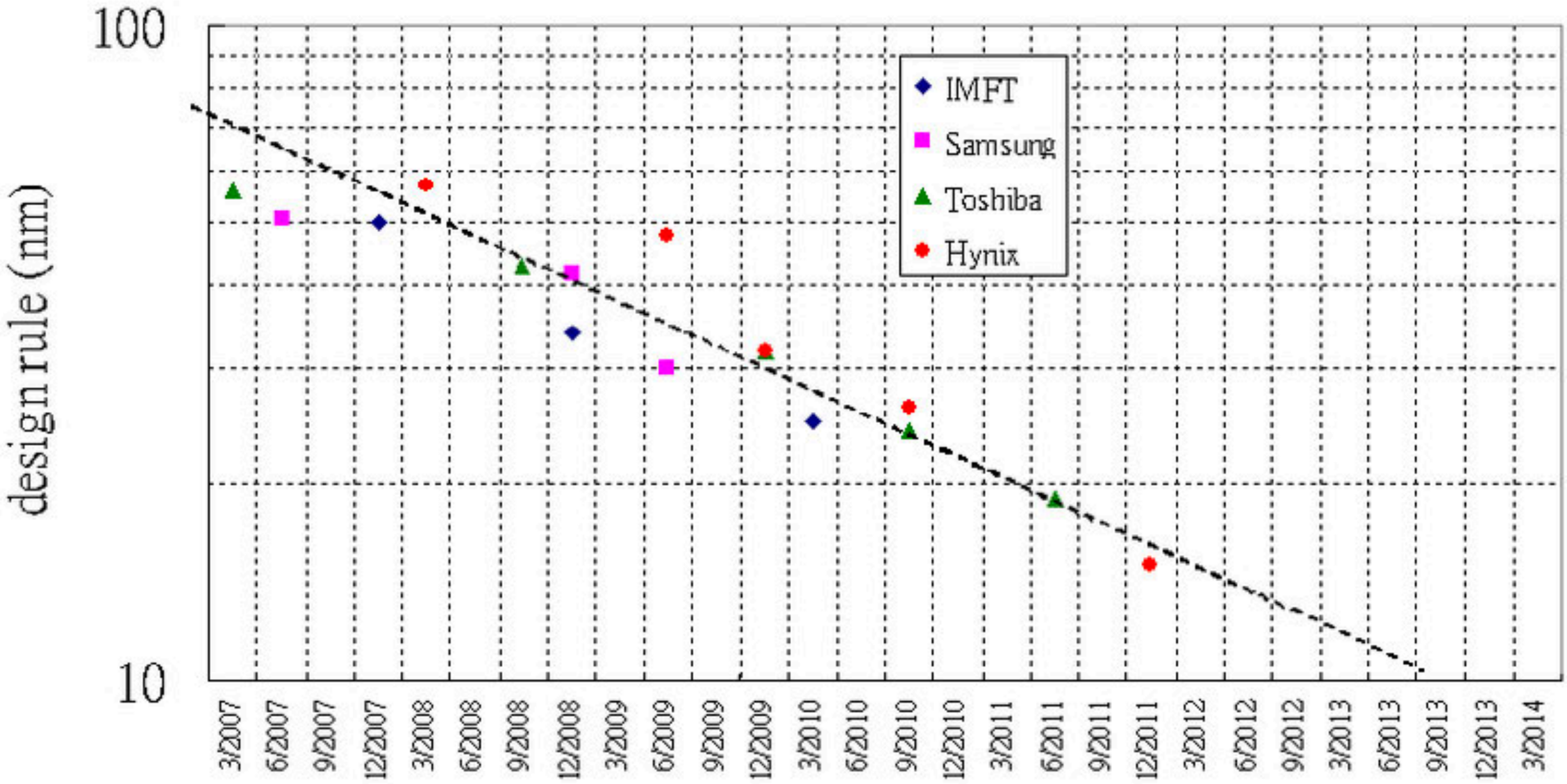
It turns out this has held true for 50 years





Exponential growth is an indicator of massive change

Moore's Law is hitting the limits of silicon-based computing

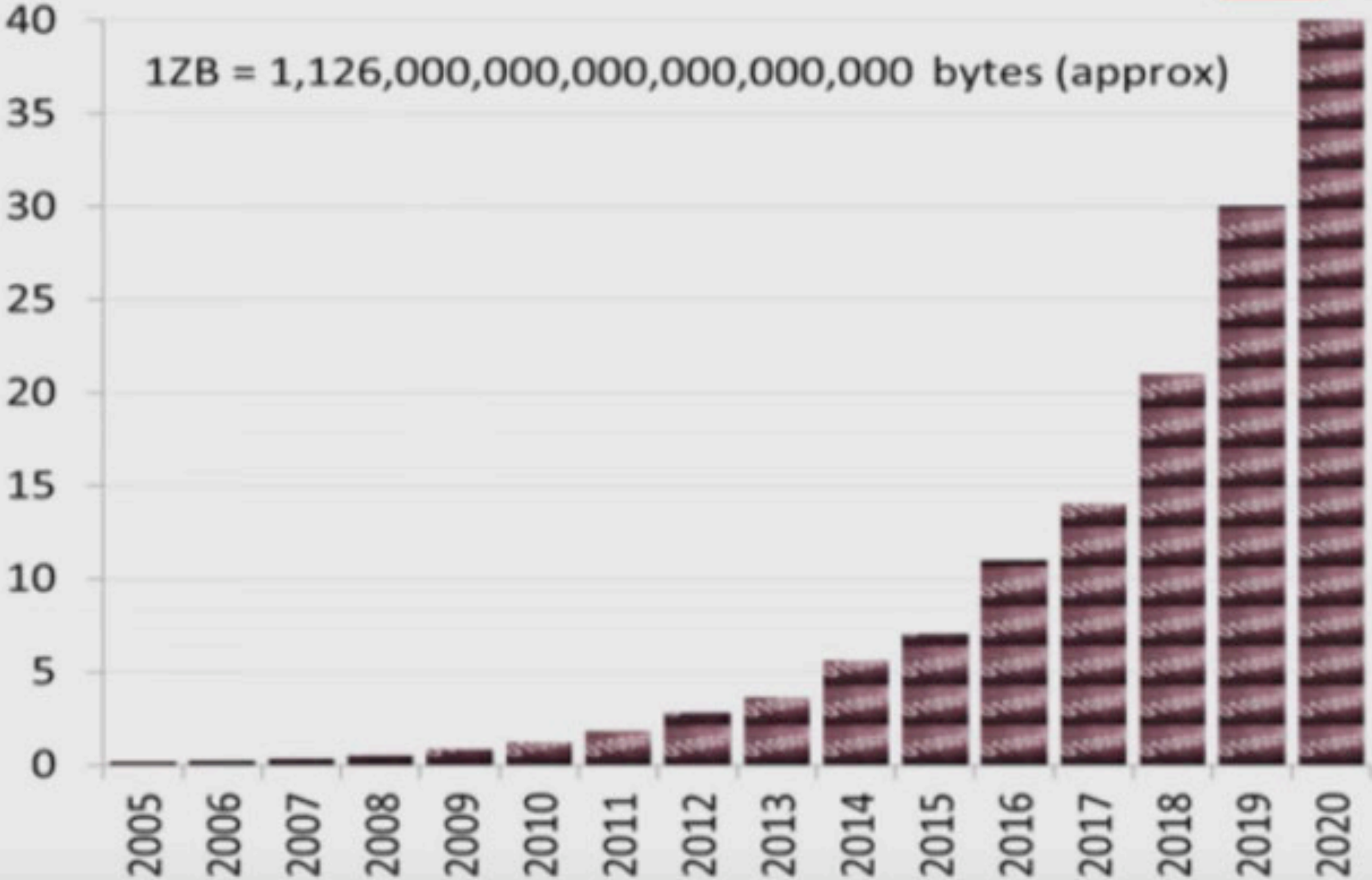


Components per mm of wafer area

All Global Data in Zettabytes

CeBIT

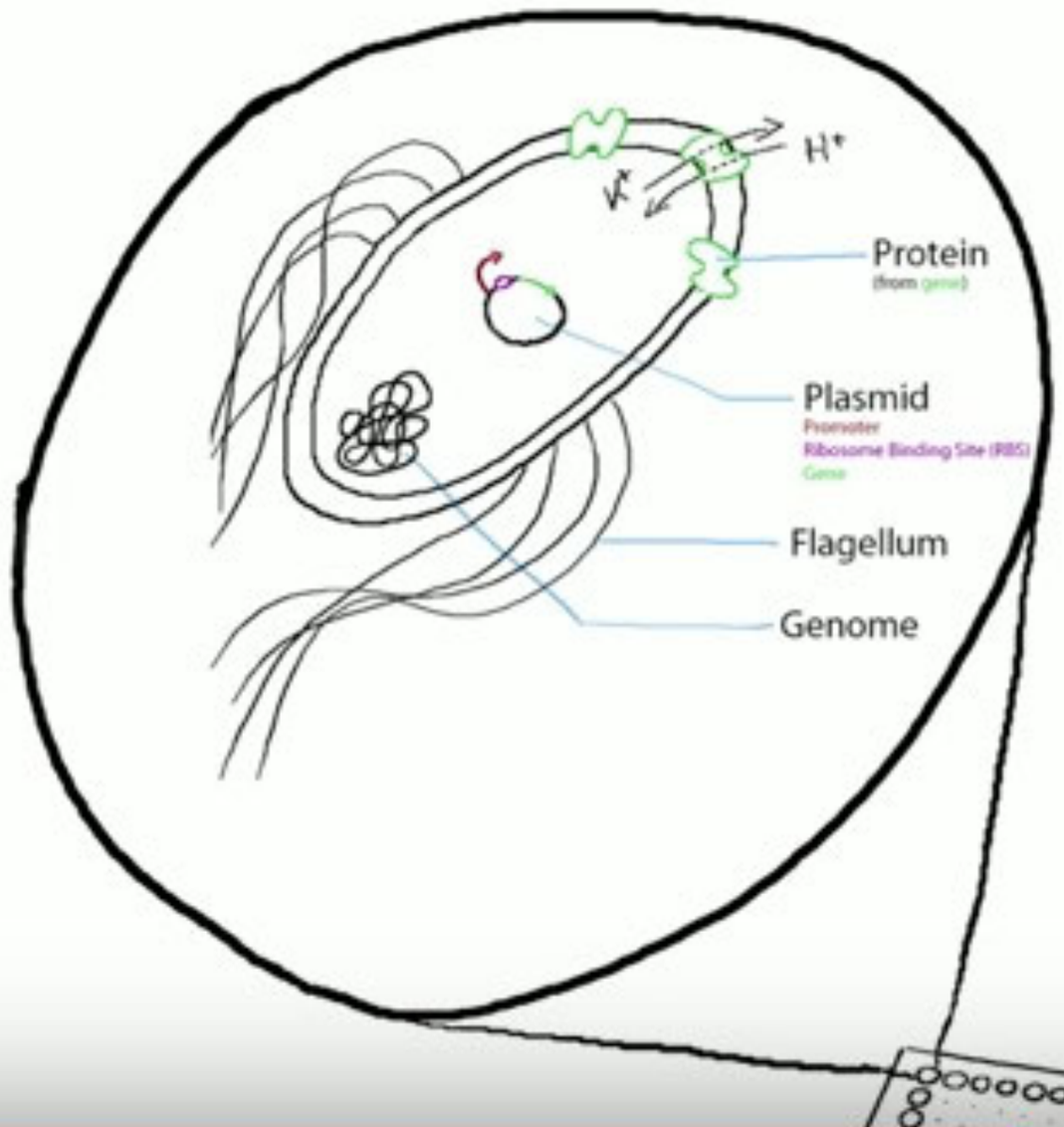
1ZB = 1,126,000,000,000,000,000,000 bytes (approx)

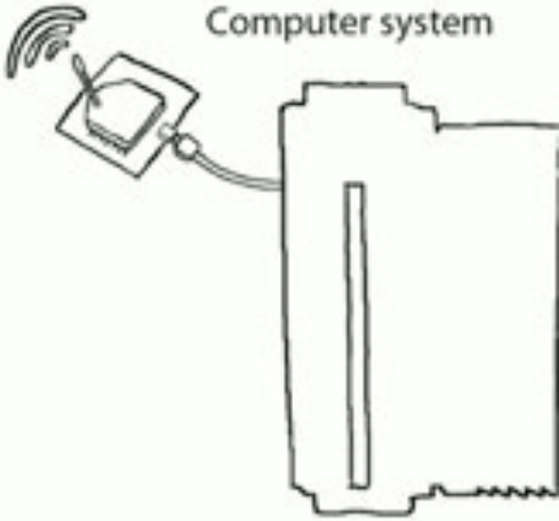


“Biotech is the new digital”

- Nicholas Negroponte

Programmable Behavior in Biology





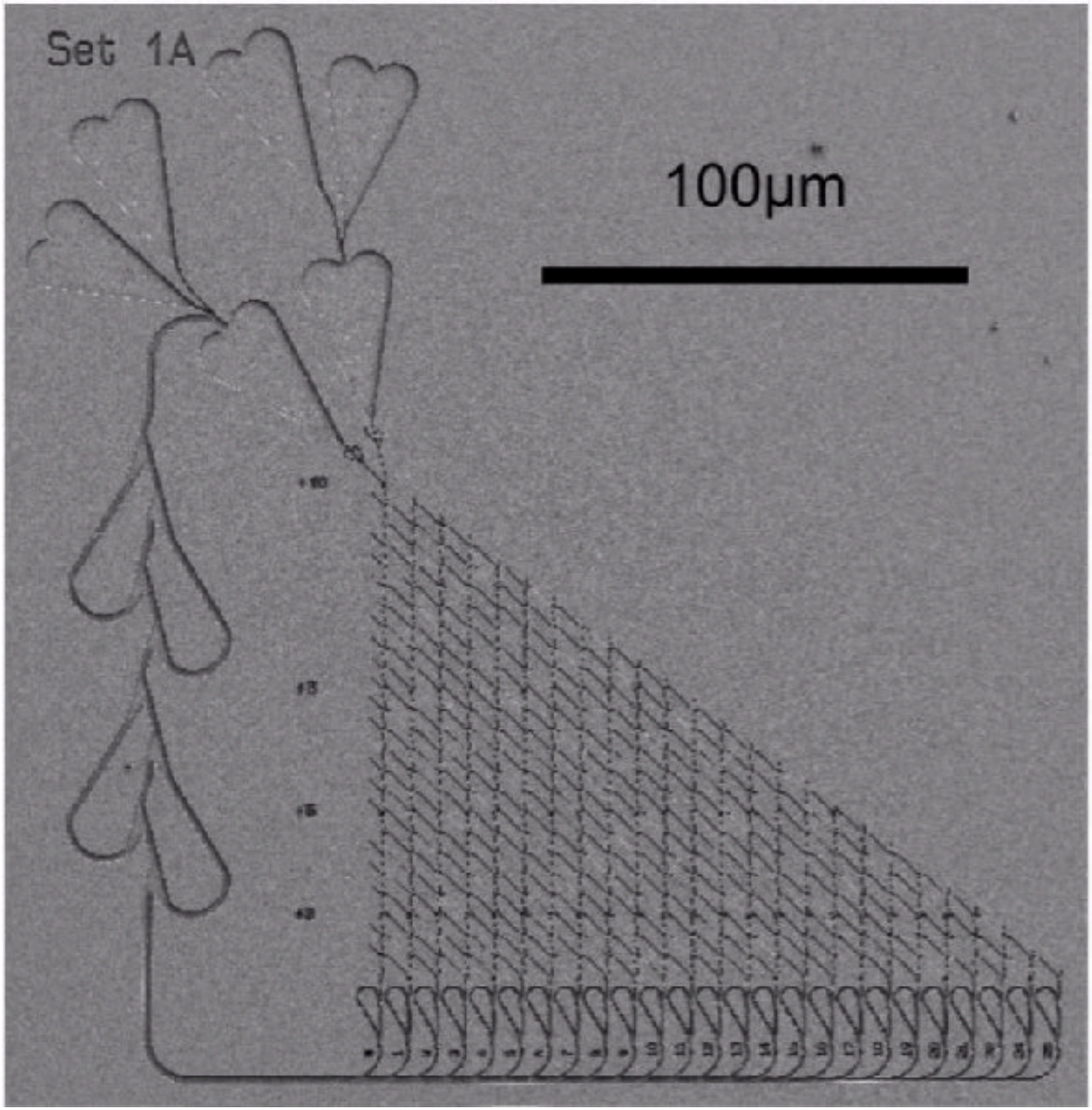
Wireless Communication

Signal amplifier

200 Million terrabytes/gram
700,000 year storage life

Biocomputers

"We are using molecular motors of the cell that have been optimized for a billion years of evolution to be highly energy efficient nanomachines,"
- **Prof. Stefan Diez,**
TU Dresden



Picture of a computation network of the biocomputer, taken with an electron microscope

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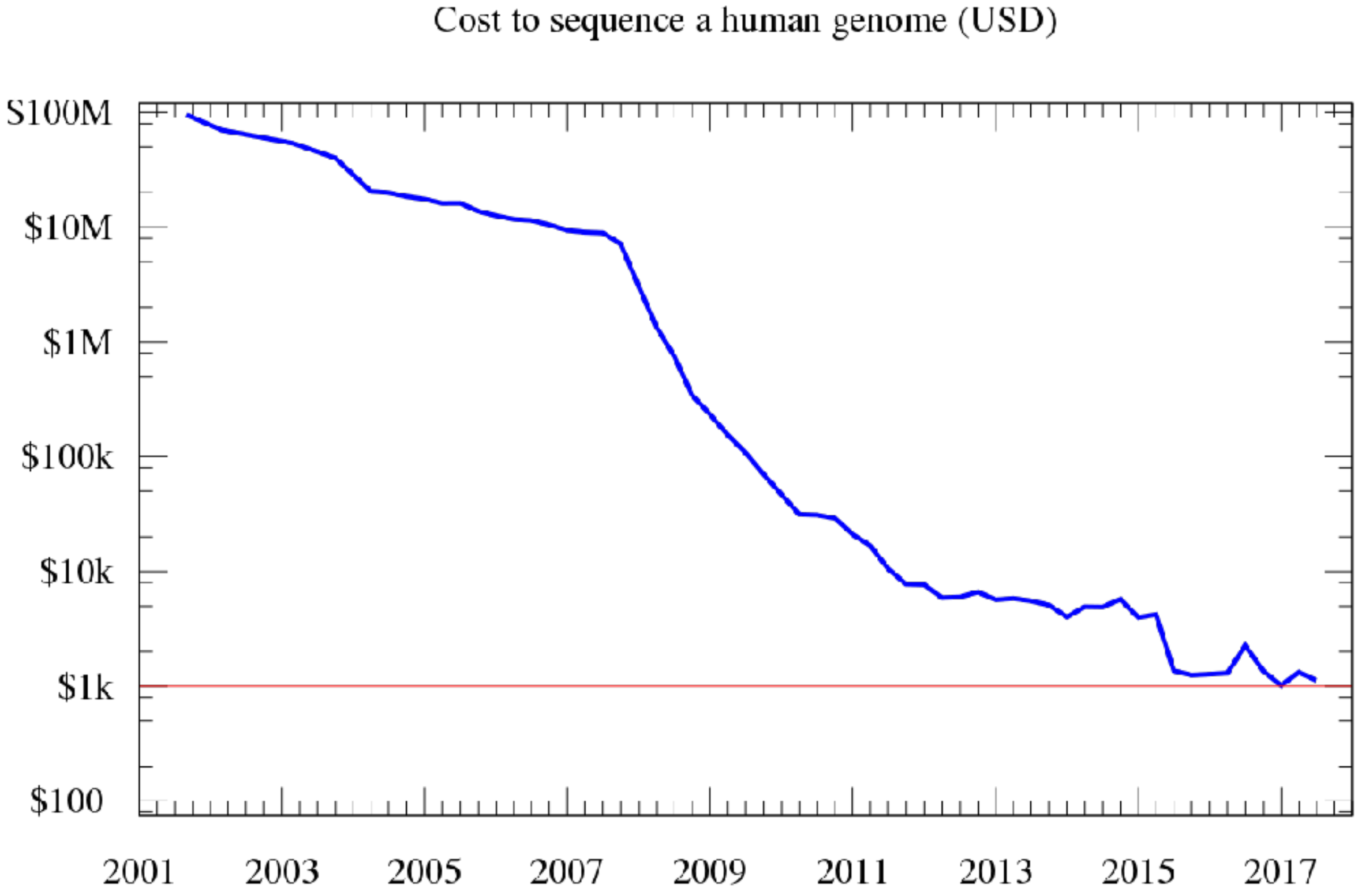

Carlson Curve - Biotechnological equivalent of Moore's Law

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1962 Computers

Cyber-physical revolution

Cyber-biological revolution

2019 DNA Sequencers

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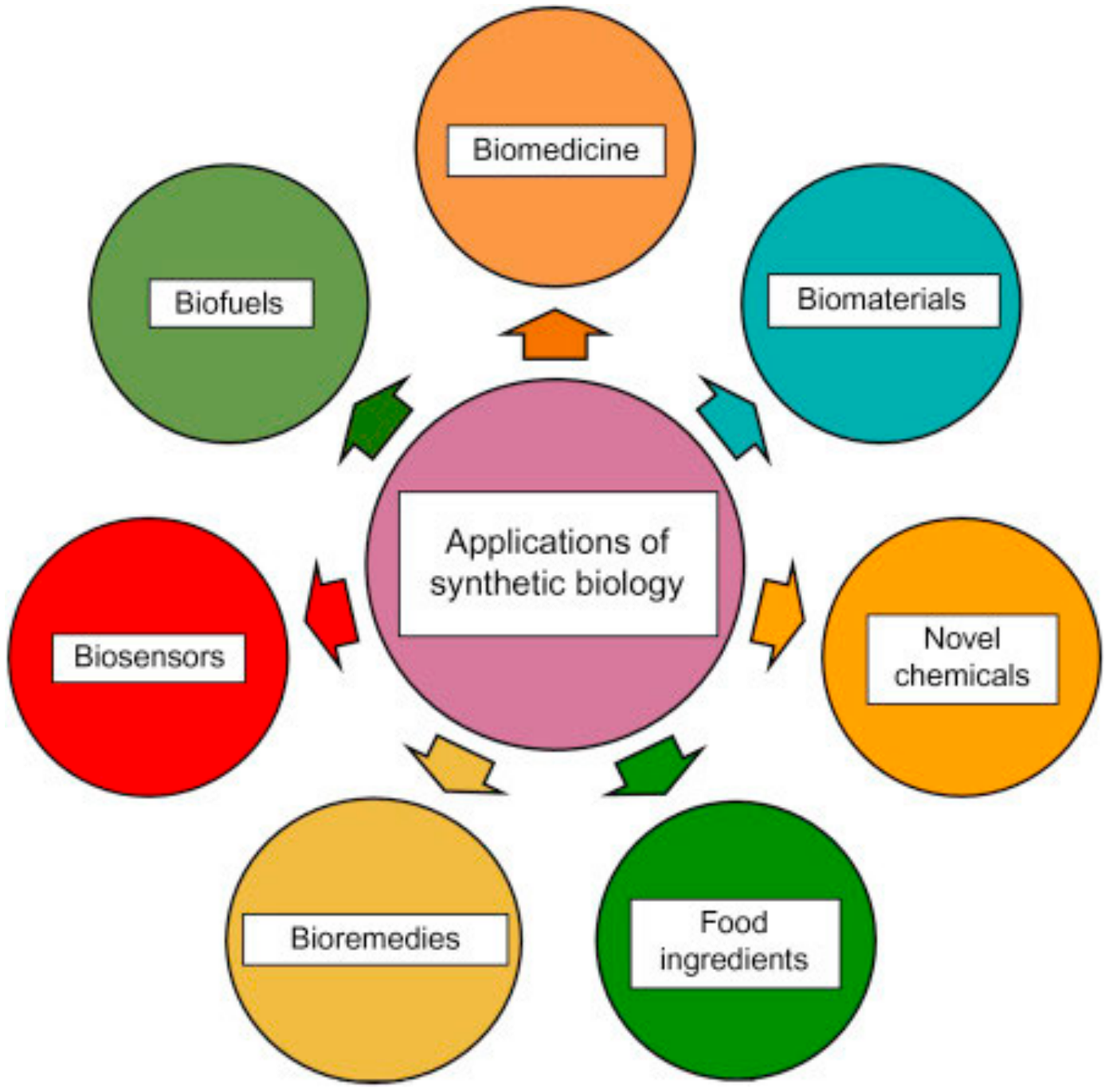
3 - Synthetic biology



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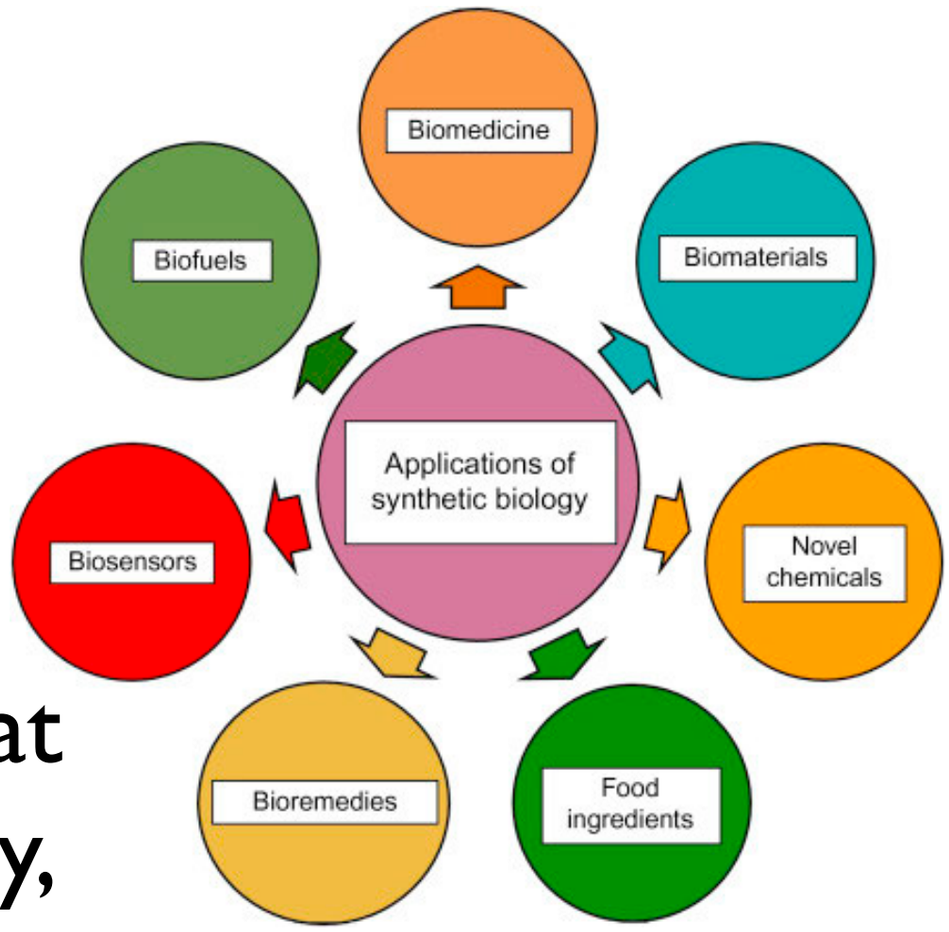
Synthetic biology

- Application of engineering principles to biology
- Design and fabricate new biological components and systems
- For example: design microbes that generate cheap alternative energy, attack tumors, deliver medicine, detect fertilizer runoff in drinking water, reveal the location of land mines…



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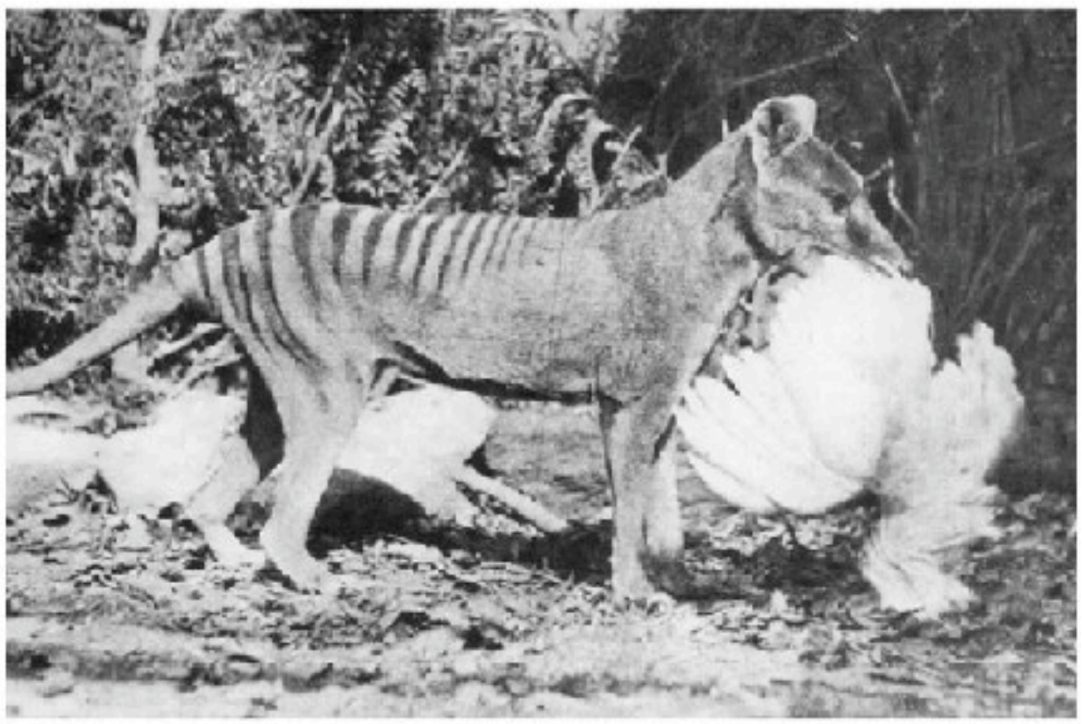
Woolly mammoth rising: can we bring extinct animals back to life?

168

After centuries of extinction, new plans emerge to bring back the passenger pigeon, Tasmanian tiger, and more

By Russ Brandom | @russellbrandom | Mar 18, 2013, 12:22pm EDT

SHARE

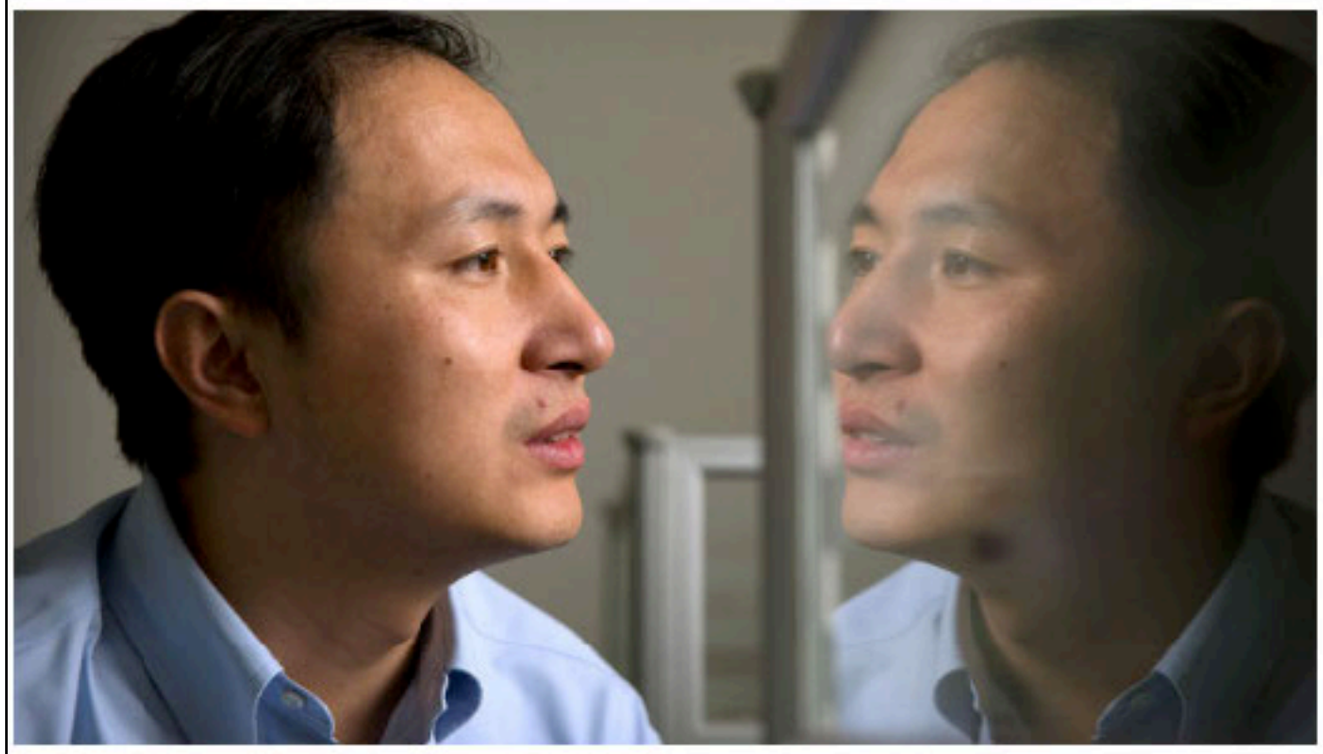


via upload.wikimedia.org

Ben Novak wants to bring back the passenger pigeon. The last living specimen died in 1914, but they ran amok through 19th century America, leaving hundreds of cadavers and plenty of DNA to pull from. Novak already has a pretty good roadmap for how it should look, thanks to the nearly identical rock pigeon genome, published in January. From there, he'll introduce the new chromosomes into the sex cells of an egg-bound rock pigeon, and hopefully, a generation later, see a passenger pigeon grow up inside a rock pigeon egg. And just like that, the most famous extinction of the 20th century is undone. Like a magic trick, Novak will pull an extinct bird out of his sleeve.

It's a long shot, but he's not alone.

Science Home News Journals Topics Careers



He Jankui told The Associated Press that he carried out his experiment to protect the twin sisters from HIV infection later in life. MARK SCHIEFELBEIN/AP PHOTO

CRISPR bombshell: Chinese researcher claims to have created gene-edited twins

By Dennis Normile | Nov. 26, 2018 , 1:10 PM

HONG KONG, CHINA—On the eve of an international summit here on genome editing, a Chinese researcher has shocked many by claiming to have altered the genomes of twin baby girls born this month in a way that will pass the modification on to future generations. The alteration is intended to make the children's cells resistant to infection by HIV, says the scientist, He Jiankui of the Southern University of Science and Technology in Shenzhen, China.

The claim—yet to be reported in a scientific paper—initiated a firestorm of criticism today, with

© 2015 Universal Studios

Seed shape

Round

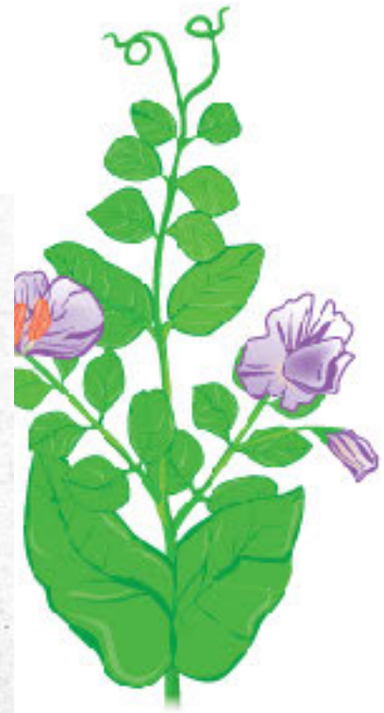
Wrinkled

Seed color

Yellow

Flower color

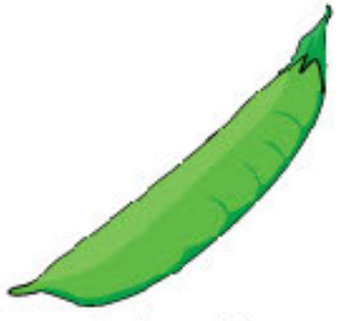
Purple



Axial

Terminal

Pod shape



Inflated

Pod color

Mendel - founder of modern genetics

Iterative Biological Design

- Computer models generate DNA sequences
- Assemble DNA molecules from synthesized building blocks
- Test in living cells and compare to simulated predictions

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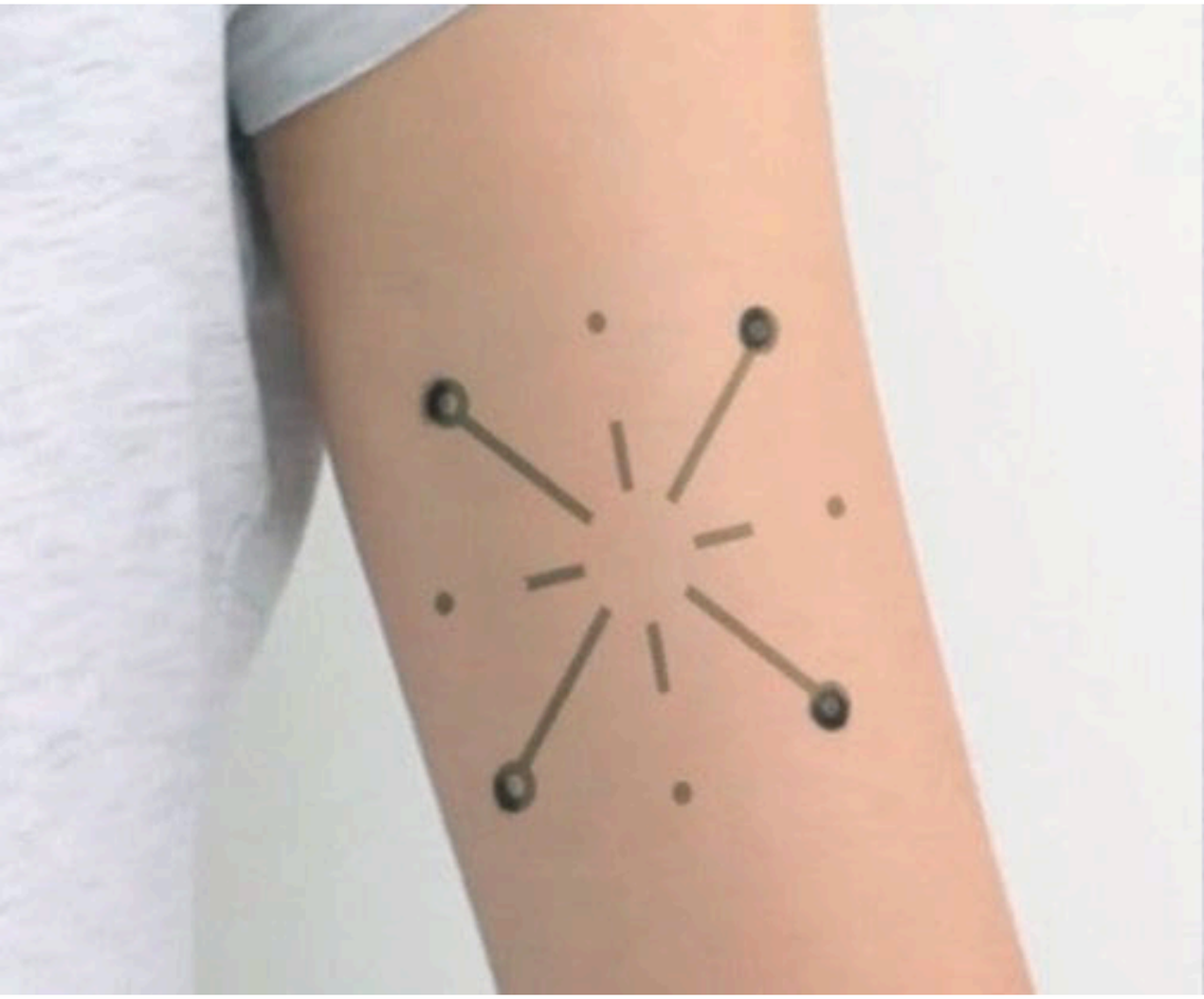
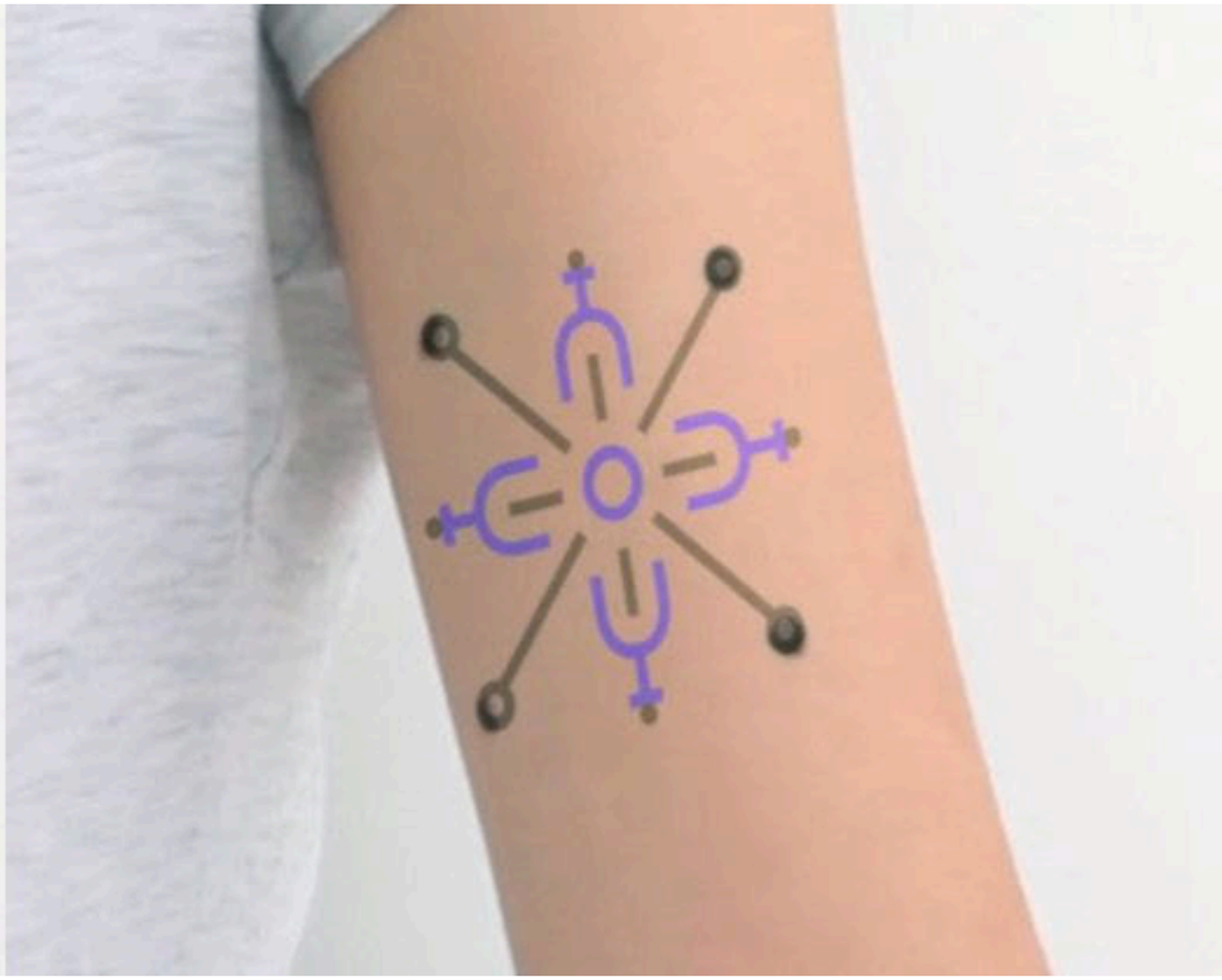
Glucose Sensitive Tattoo





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Synthetic Biology

based on standard parts

- About
- What is iGEM?
- iGEM Values
- Previous Competitions
- Leadership
- Staff
- Financials
- FAQ
- Contact
- Blog

Programs

- iGEM Competition
- Labs Program
- Parts Registry
- Alumni

Welcome to iGEM

The iGEM Foundation is dedicated to education and competition, advancement of synthetic biology, and the development of open community and collaboration.

The main program at the iGEM Foundation is the International Genetically Engineered Machine (iGEM) Competition. The iGEM Competition is the premiere student competition in Synthetic Biology. Since 2004, participants of the competition have experienced education, teamwork, sharing, and more in a unique competition setting.

iGEM is also much more than a competition; our community has a long history of involving students and the public in the development of the new field of synthetic biology.

iGEM 2016 Competition

Late registration ends May 1! Late registration runs from April 1 to May 1 and is an extra $500 USD.

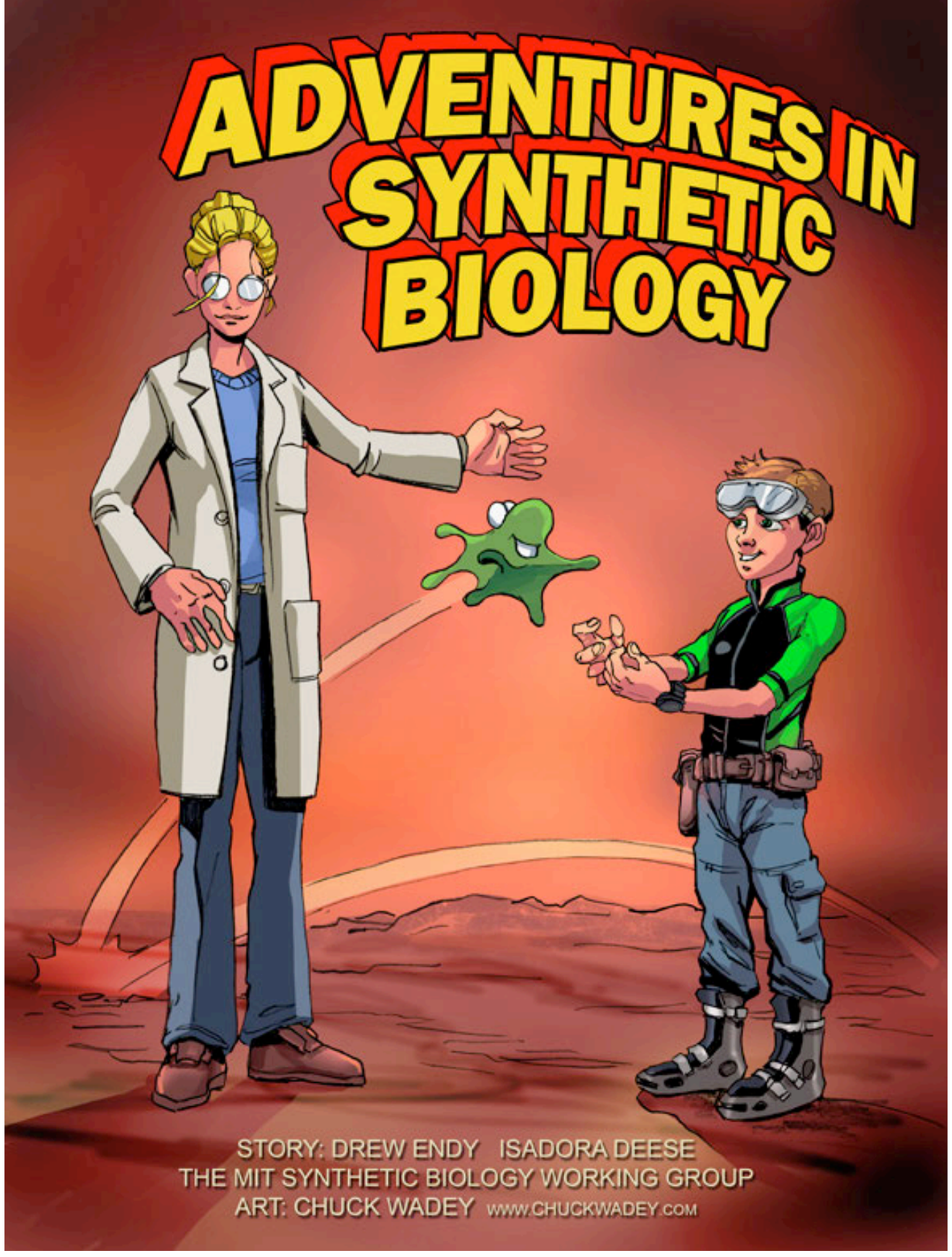
Visit 2016.igem.org for more information.

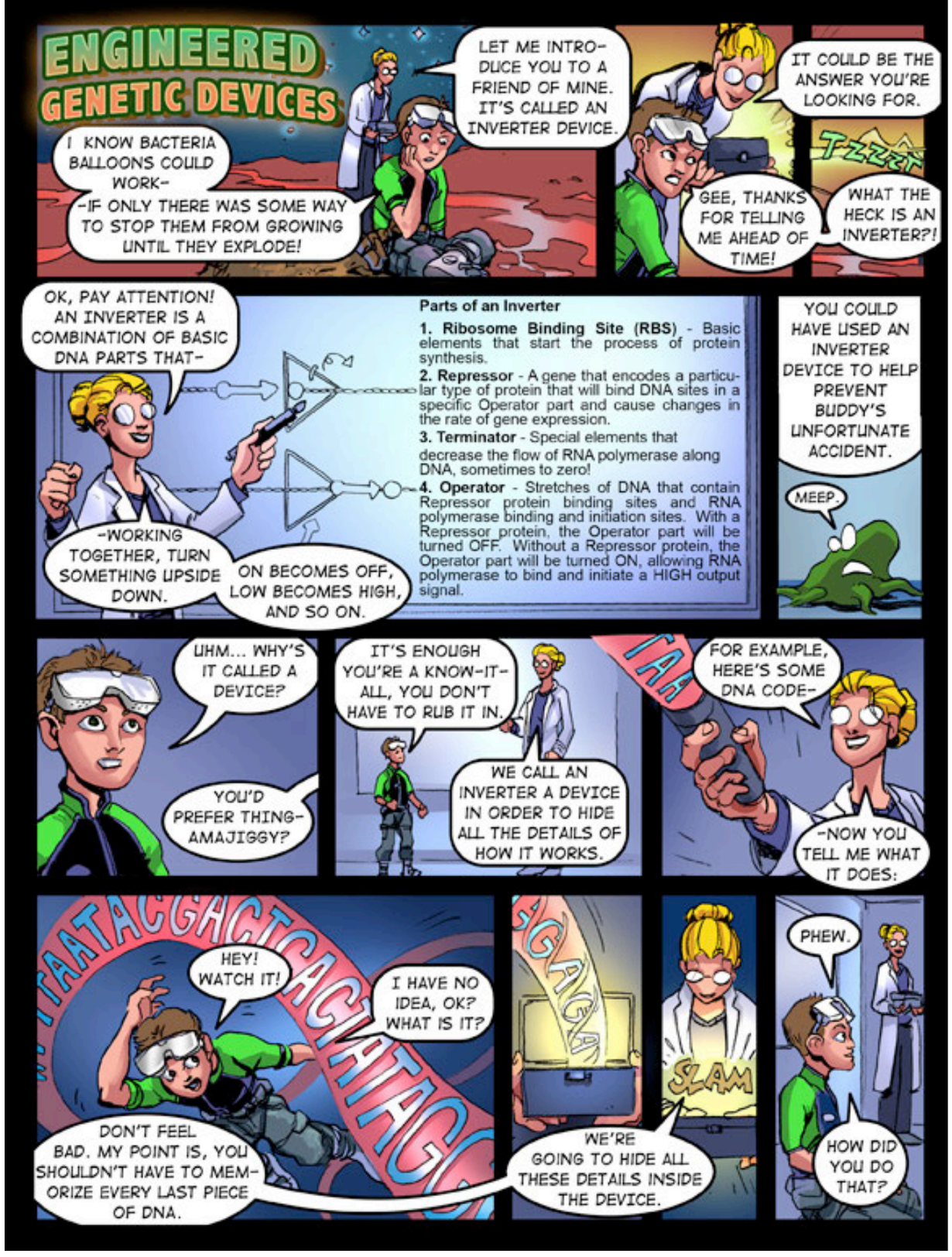
Giant Jamboree

October 27 - 31 -- Hynes Convention Center -- Boston
Join us at the iGEM 2016 Giant Jamboree! More information about the Giant Jamboree will soon be available at 2016.igem.org/Giant_Jamboree. You can find information about the iGEM 2015 Giant Jamboree here.

iGEM 2016 Announcements

IDT
INTEGRATED DNA TECHNOLOGIES
Receive up to 20 kb of free DNA for your iGEM project
Get my free DNA »





biobuilder.org

Resources, lab kits, workshops

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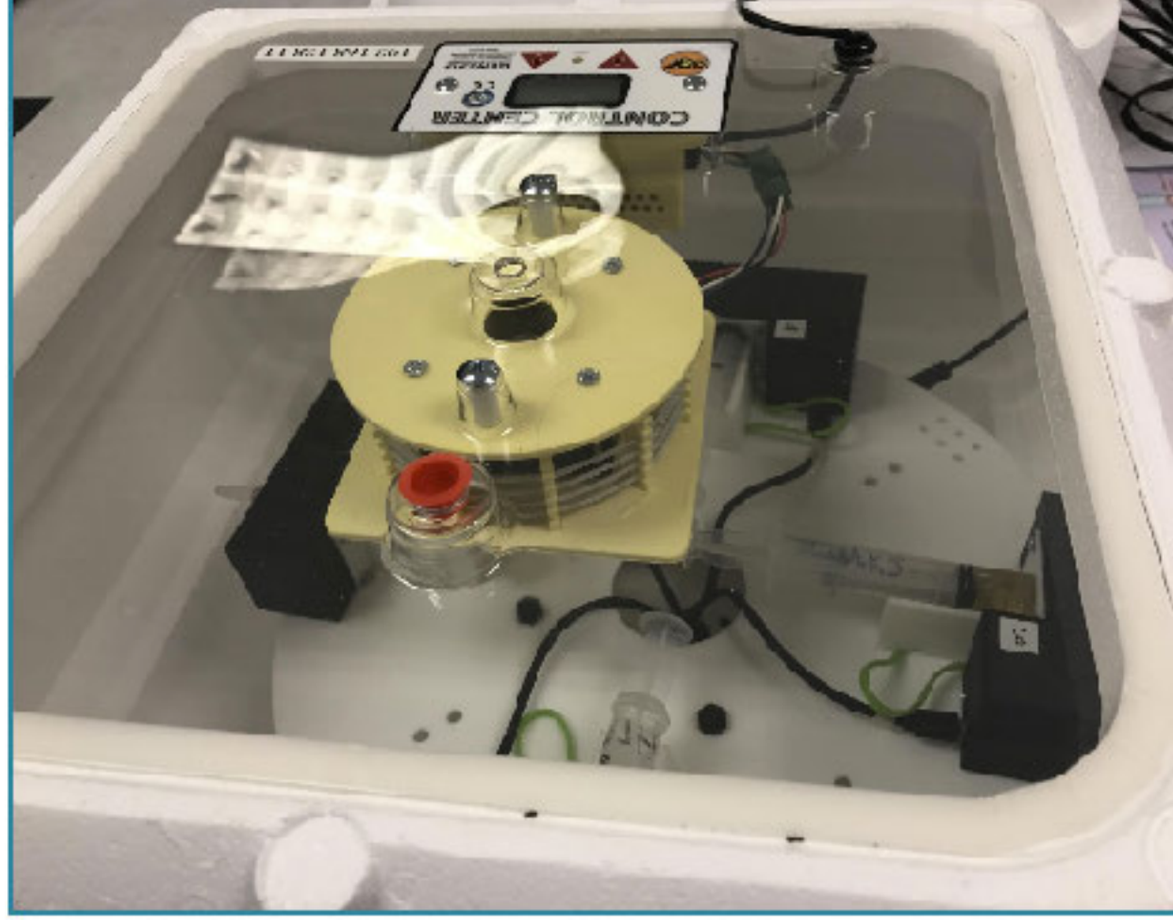
sylviamartinez.com

biomakerlab

- Prototype stage: a low cost mobile lab device used to genetically modify and fabricate (grow) bacterial or yeast cells
- 3 units of HS curriculum being developed with UPenn (PennDesign Emerging Design Practices, and Grad School of Education)



Justice Walker, grad student, teaching HS

© 2019 Sylvia Martinez

- Elevates engineering design to same level of importance as scientific inquiry. "*The purpose of defining "engineering" more broadly in the Framework and NGSS is to emphasize* ***engineering design*** *practices that all citizens should learn.*"

- Engineering design standards - Appendix 1
- Two reasons:
  - Aspirational: Scientific challenges are motivating and kids want to make the world a better place
  - Practical: Kids want to do real things, and these lessons "stick."

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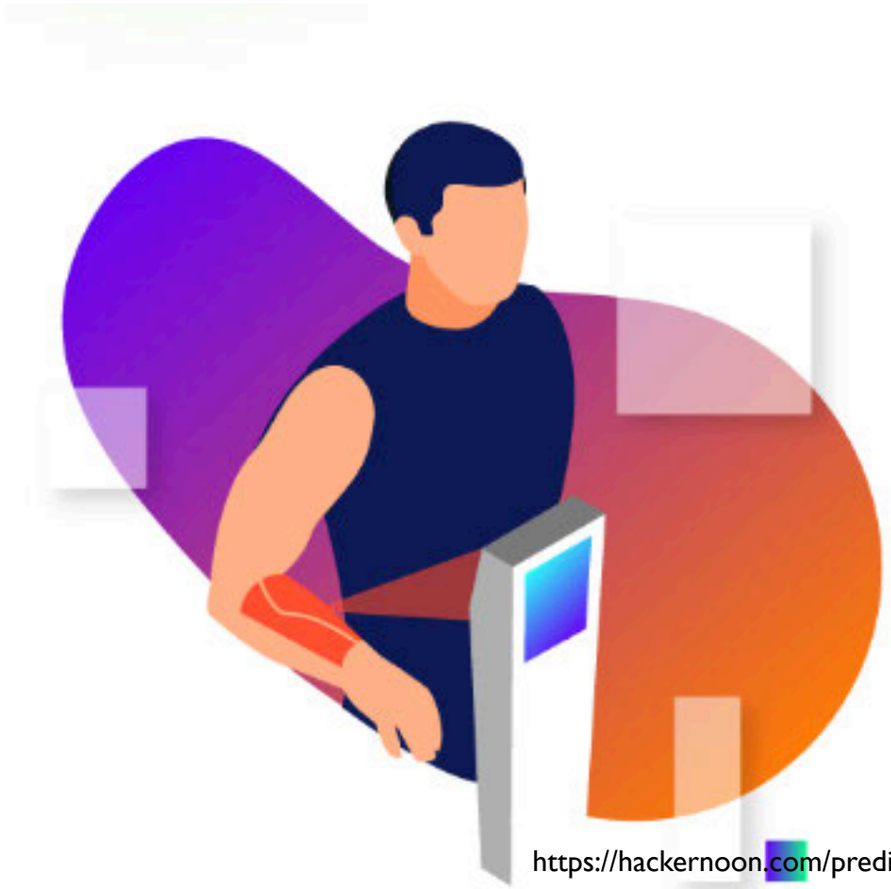
(c) 2015 Sylvia Martinez

4 - AR & VR

- Augmented Reality adds a virtual layer to the real world (Pokemon Go, heads-up displays)
- Virtual Reality builds a virtual world you can view and manipulate

Future applications
shopping
virtual experiences
medicine
navigation
games



https://hackernoon.com/predictions-for-the-future-of-augmented-reality-63c7b8c9d794

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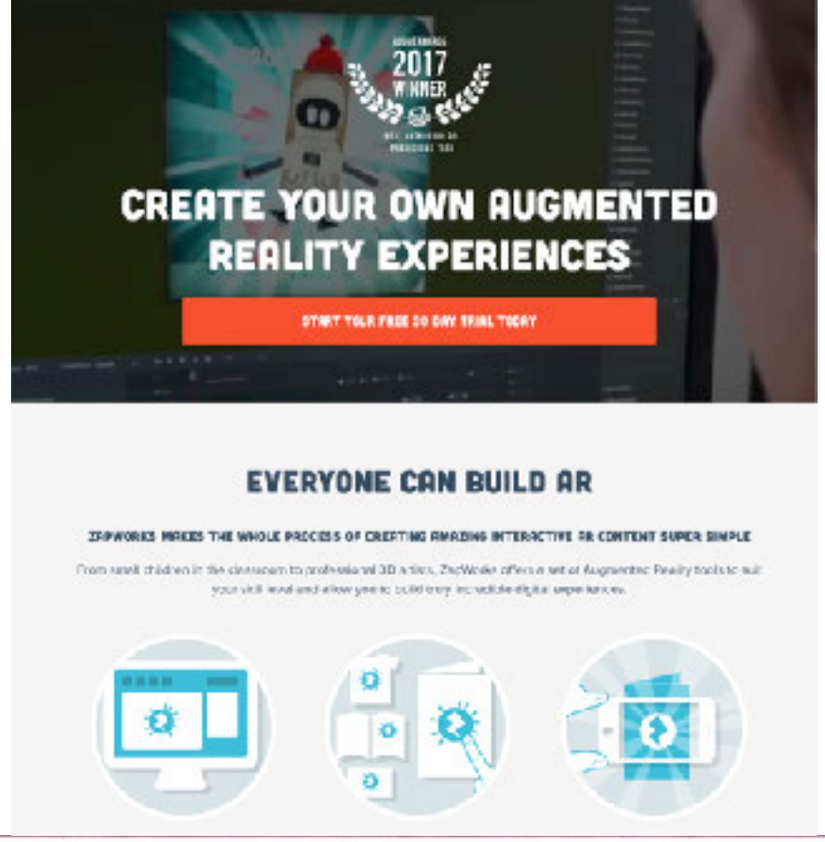
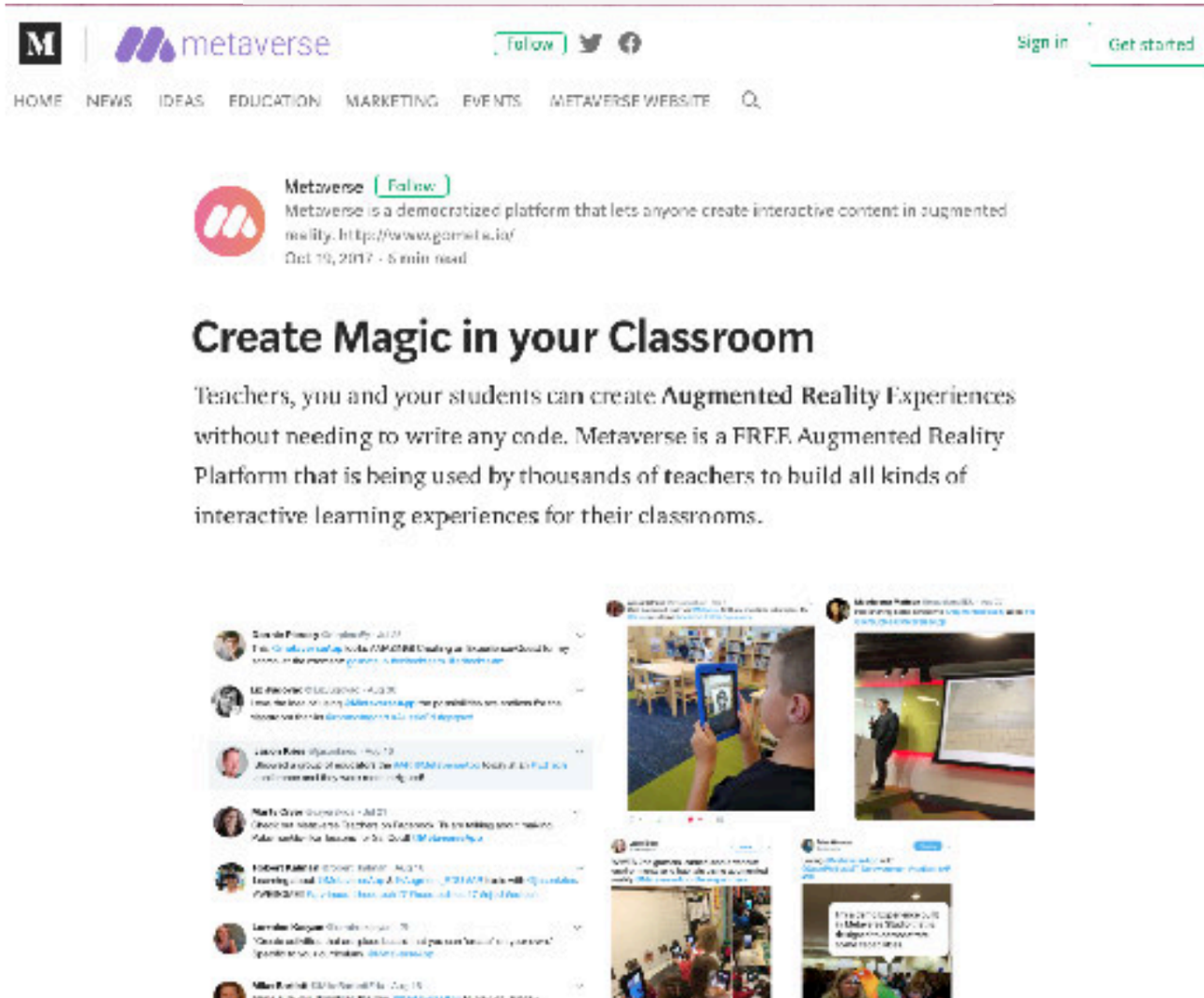
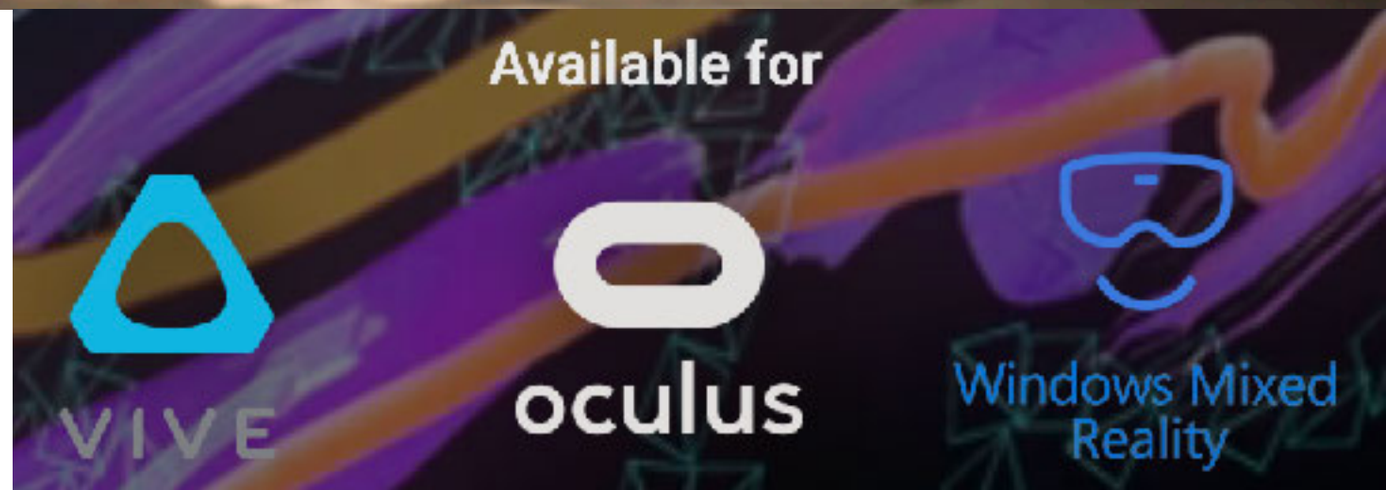
Google Cardboard





Tilt Brush

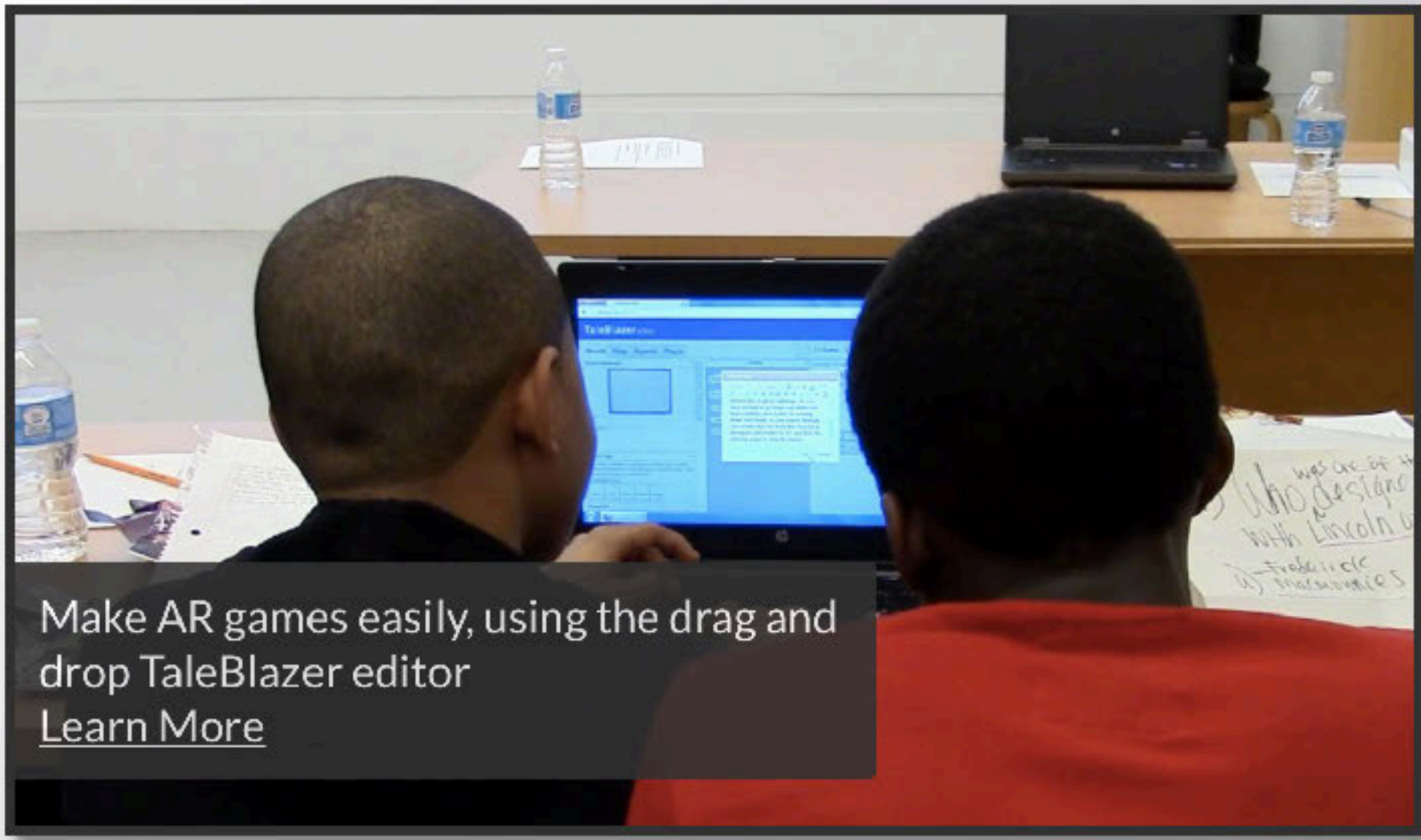


AUTODESK.

LIVE Design

Innovative workflows to create interactive visualizations and virtual reality experiences.

© 2019 Sylvia Martinez



Play games

Make games

Featured Partner: Explore history

iCSI Project

Play — or make your own — location-based augmented reality (AR) games with TaleBlazer for Android and iOS

Playing Games

How to Play

Featured Games

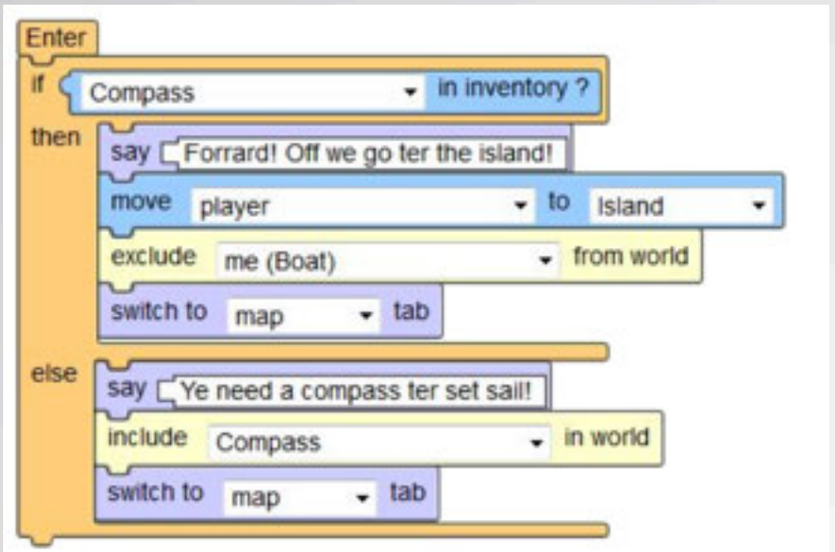
Supported Devices

Making Games

Getting Started

Demo Games/Tutorials

TaleBlazer Editor



5 - Robots

WIRED The Great Tech Panic: Robots Won't Take All Our Jobs

Will robots take your job? Humans ignore the coming AI revolution at their peril.

Artificial intelligence aims to replace the human mind, not simply make industry more efficient.

Inc. CREATE YOUR COMPANY

TECHNOLOGY

Robots Will Take Your Job. Here's Why You Should Be Excited.

Here's why artificial intelligence will replace most repetitive jobs.

By Ben Kuth Cbl. brownlabs.com @bennuth

APR 20, 2018 @ 06:27 AM 4,086

Why Robots Will Not Take Over Human Jobs

Andrew Arnold, U30 CONTRIBUTOR

FULL BIO

Opinions expressed by Forbes Contributors are their own.

EMERGE AMERICAS

Apple co-founder Steve Wozniak: Why robots won't be taking our jobs for hundreds of years

Catherine Clifford | 8:00 AM ET Tue, 13 June 2017

Think robots will take your job? Here's why that won't happen

The Conversation By Jeff Borland, University of Melbourne

Posted 26 Nov 2017, 9:21pm

No, A Robot (Probably) Won't Take Your Job

But you'll need to learn to love your new chatbot coworker.

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Boston Dynamics

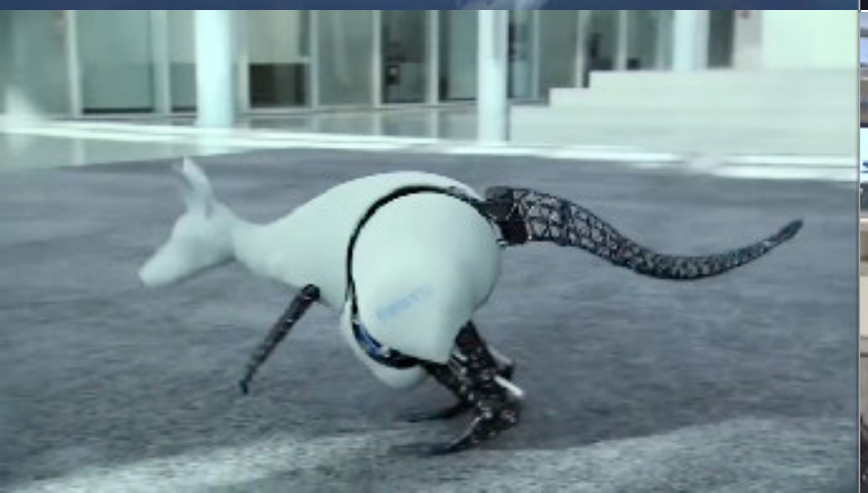
BostonDynamics

6. Valkyrie
NASA

JR
STUDIOS
Boston Dynamics

Boston Dynamics

Boston Dynamics



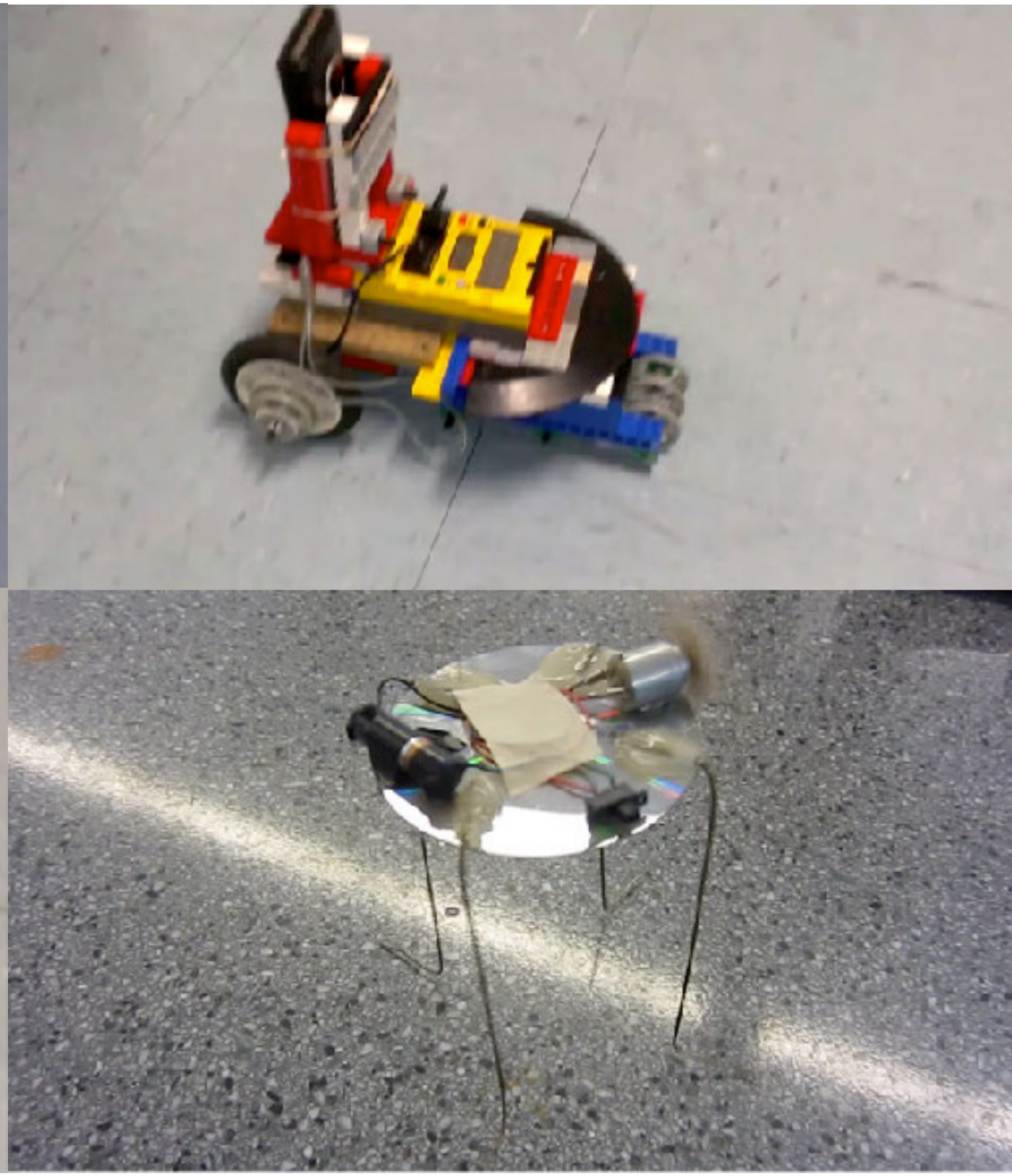
SIMO
4. Asimo New Generation

Boston Dynamics
3. Atlas Robot

Simple can be Smart

The Future is Simple

Smart is expensive
Precision is expensive



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obots then edge-follow until they enter the desired shape,

Collectives in nature can have millions of individuals that cooperat
form complex structures.

6 - AI and machine learning

- Algorithms that improve through experience
- What does intelligence mean?
- What does it mean to be human?

Hawking: Creating AI Could Be the Biggest Event in the History of Our Civilization

Stephen Hawking/Reddit

by Dom Galeon and Kristin Houser | October 20, 2016 | Artificial Intelligence

SHARE

IN BRIEF

- At the launch of the Leverhulme Centre for the Future of Intelligence (CFI), the famed scientist warned of a potentially grave future given the rise of AI.
- The work done at CFI could have far-reaching implications for the future of AI, helping shape how the technology is used and regulated.

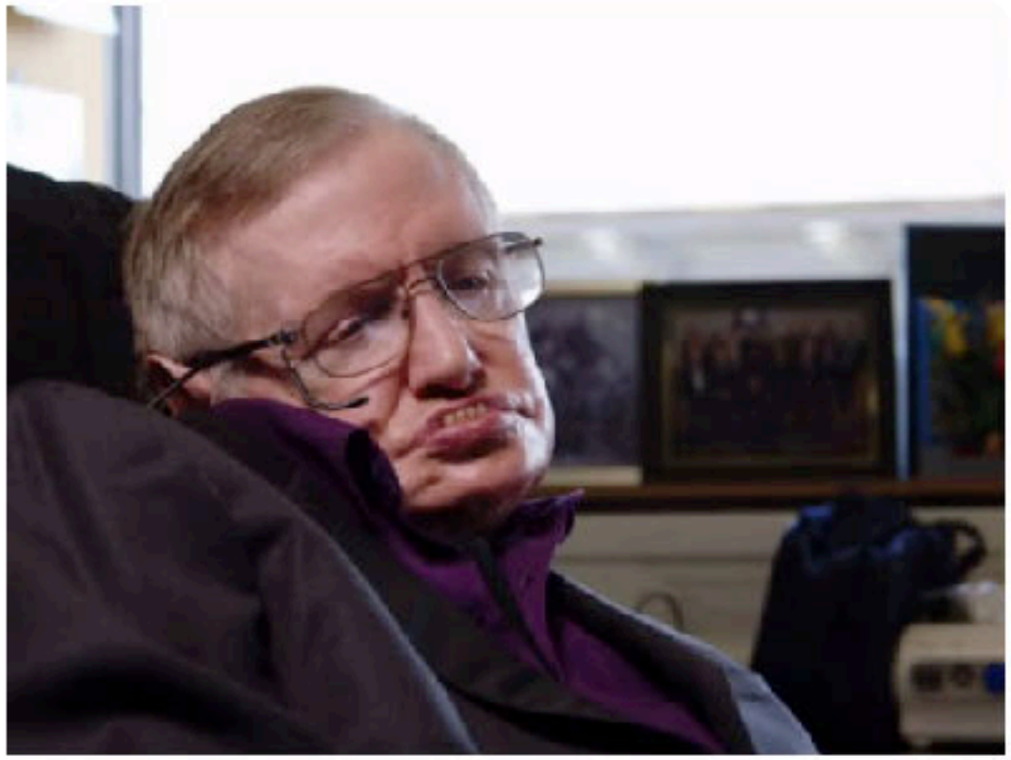
#artificial intelligence
#leverhulme centre for the future of intelligence
#Stephen Hawking

.com

Stephen Hawking: 'Artificial Intelligence Could Spell The End Of The Human Race'

Dave Smith Dec. 2, 2014, 10:00 AM

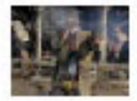
Professor Stephen Hawking is getting an upgrade to the technology that allows him to communicate. But the legendary physicist is fully aware of the implications of improving the artificial intelligence software that is so valuable to him.



YouTube

Earlier this year, Hawking spelled out the potential dangers of artificial intelligence: If we can make

RECOMMENDED FOR YOU



The 38 hottest video games you shouldn't miss in 2018

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FINANCIAL GUIDANCE FROM

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What AI can't do (yet)

- Learn like a human (from very little experience)
- Critically examine its own programming
- Expand beyond its capabilities (a chess playing program won't suddenly start making dinner)
- End a war

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How (and Why) Ed-Tech Companies Are Tracking Students' Feelings

Florida 8th graders Shayna Thomas, left, and Kenna Wloncek are among the 200,000 students whose clicks and keystrokes have been collected as part of an effort by researchers to teach a software platform called Algebra Nation how to pinpoint student emotions and engagement.
—Josh Ritchie for Education Week

A push to use new technology to understand the 'whole child' is sparking privacy fears

By Benjamin Herold

REGIST
Get more s
Email
Password
Select your
Keep me
Send me
By clicking "
Quality C
Finance and
WEBINAR JU
REGISTER NO
'When A
Students Fi
WEBINAR JU
REGISTER NO

Creepy or cool?

Critics say…

"Psycho-compulsion"
"Behavior modification"
Data breaches

Proponents say…

"Empathy technology"
"focus-enhancing mind coach"
"manage digital distractions"

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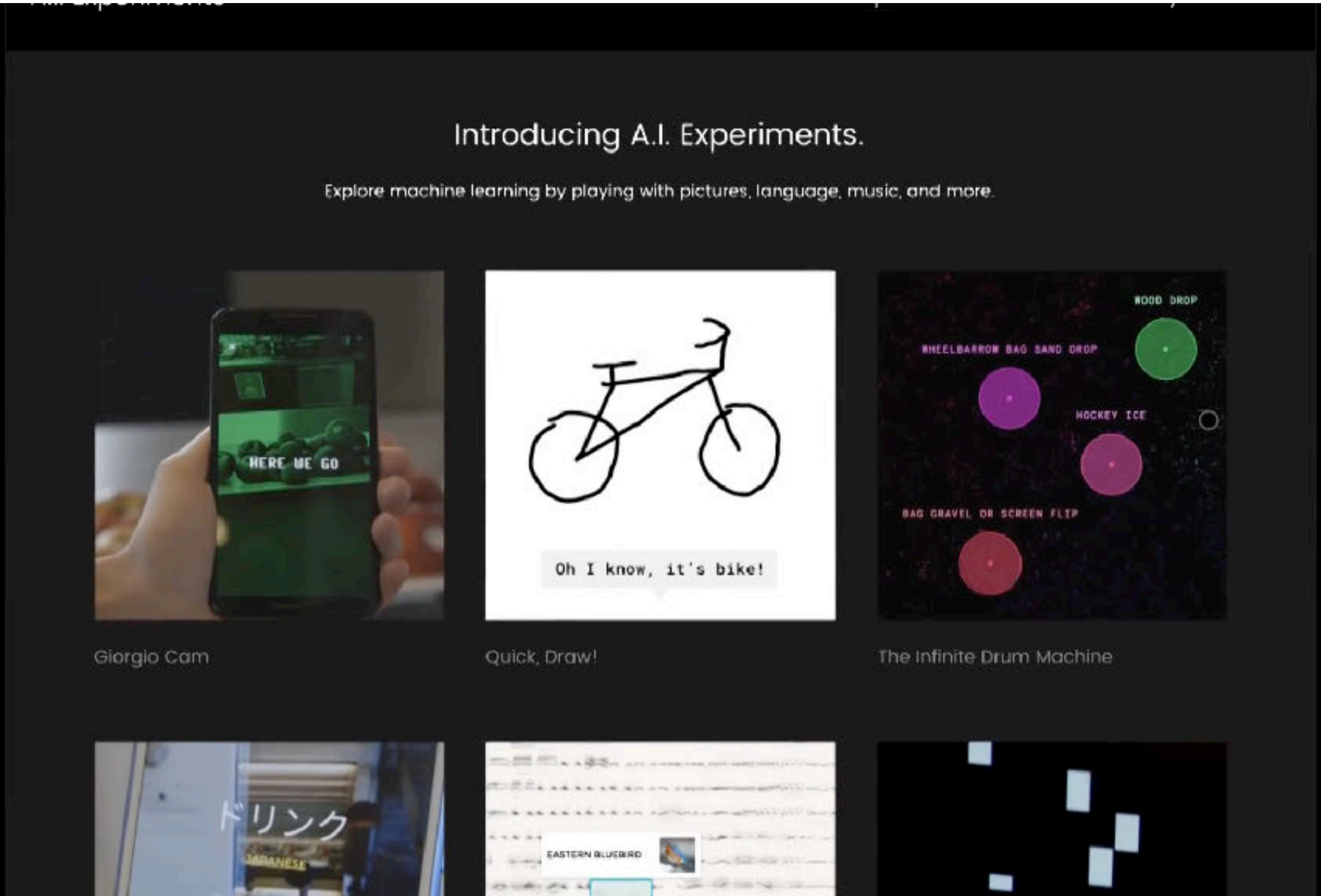
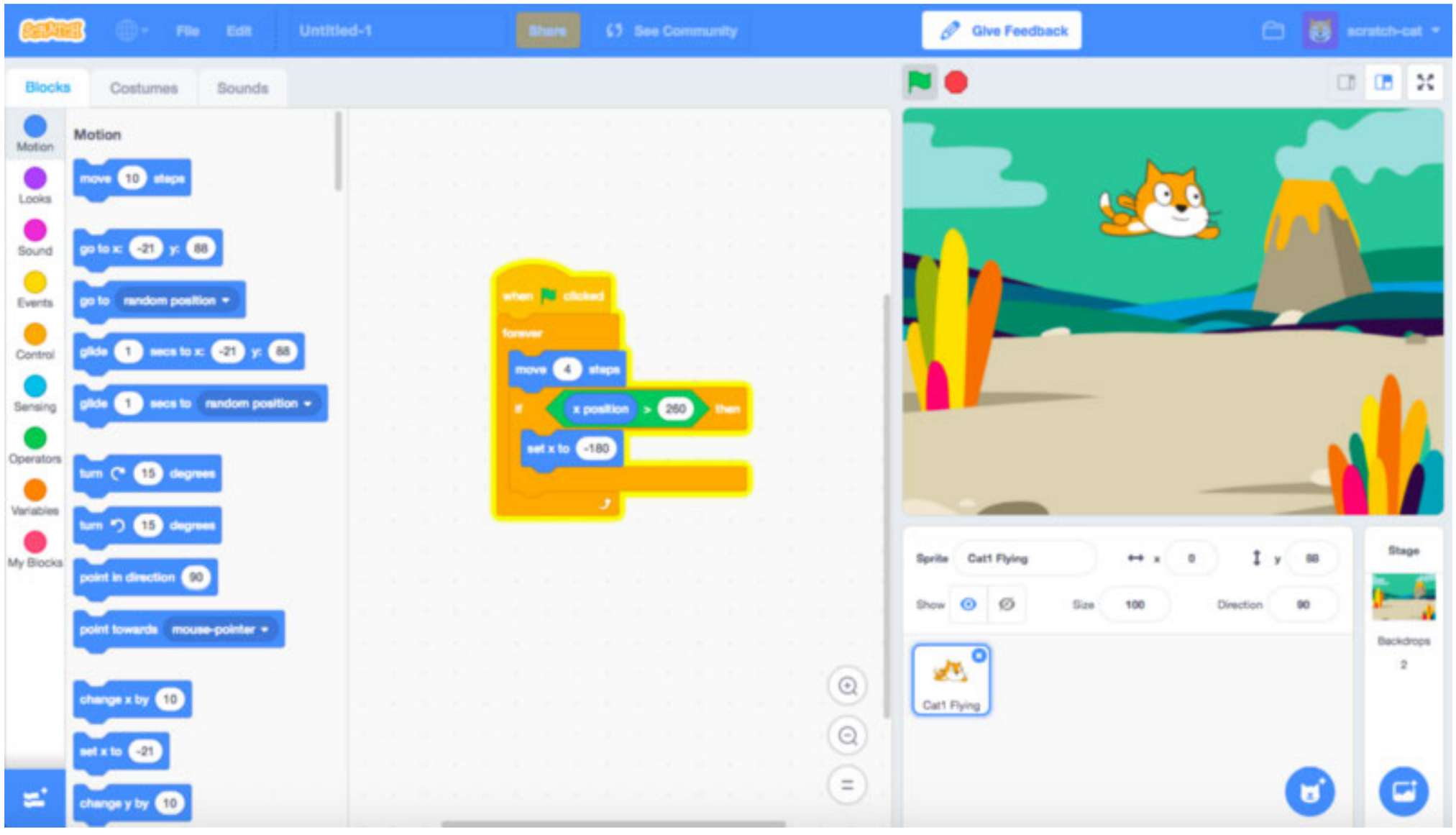
How do you feel about this?

Google AI Experiments



Scratch 3



Tablets, microcontroller connections, AI/VR,
LEGO WeDo & EV3, new sound and graphic options

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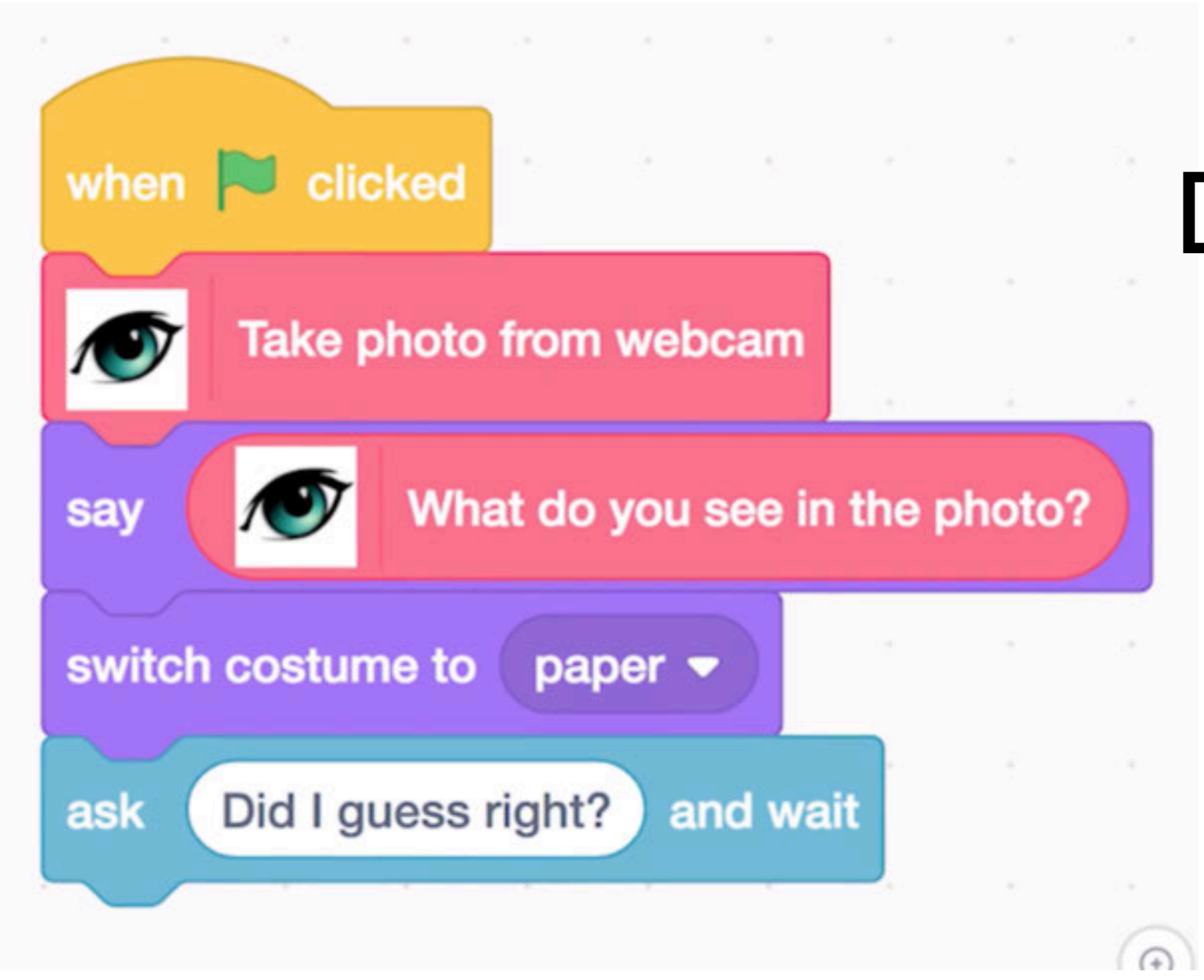
Cognimates

cognimates.me



Design in Scratch
Build games
Program robots
Train AI models

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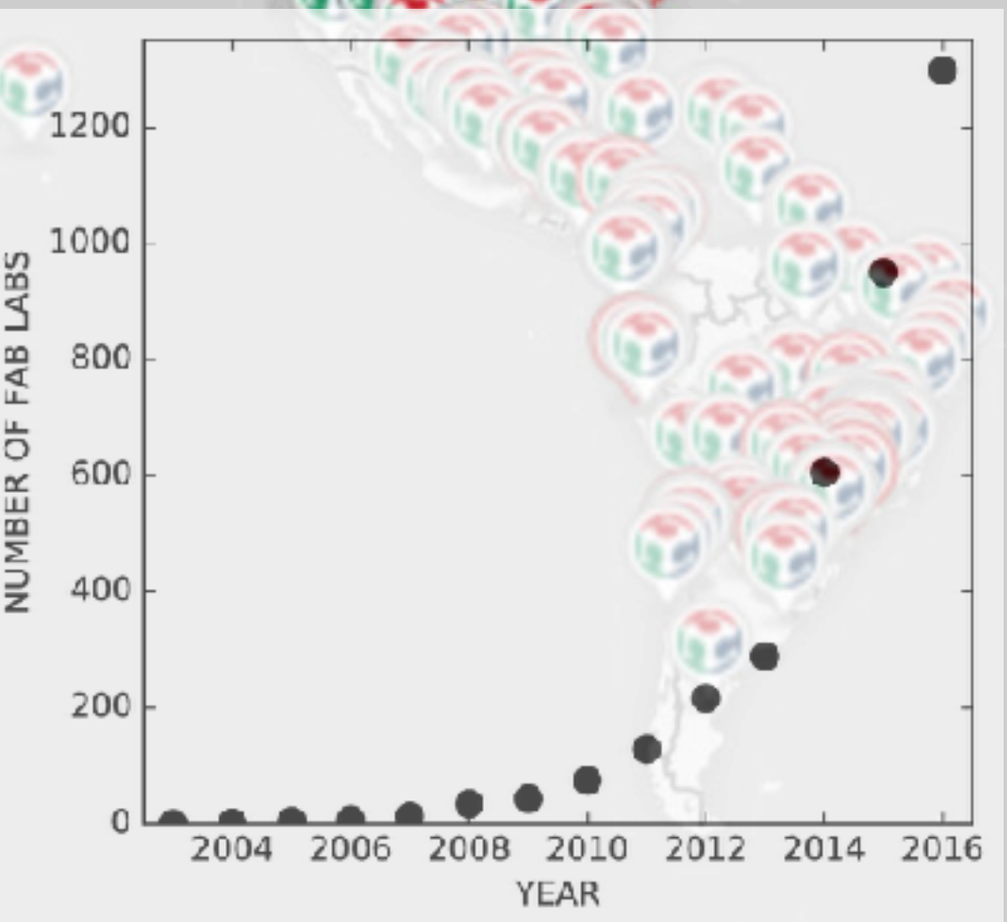
7 - Small Solutions for Big Problems

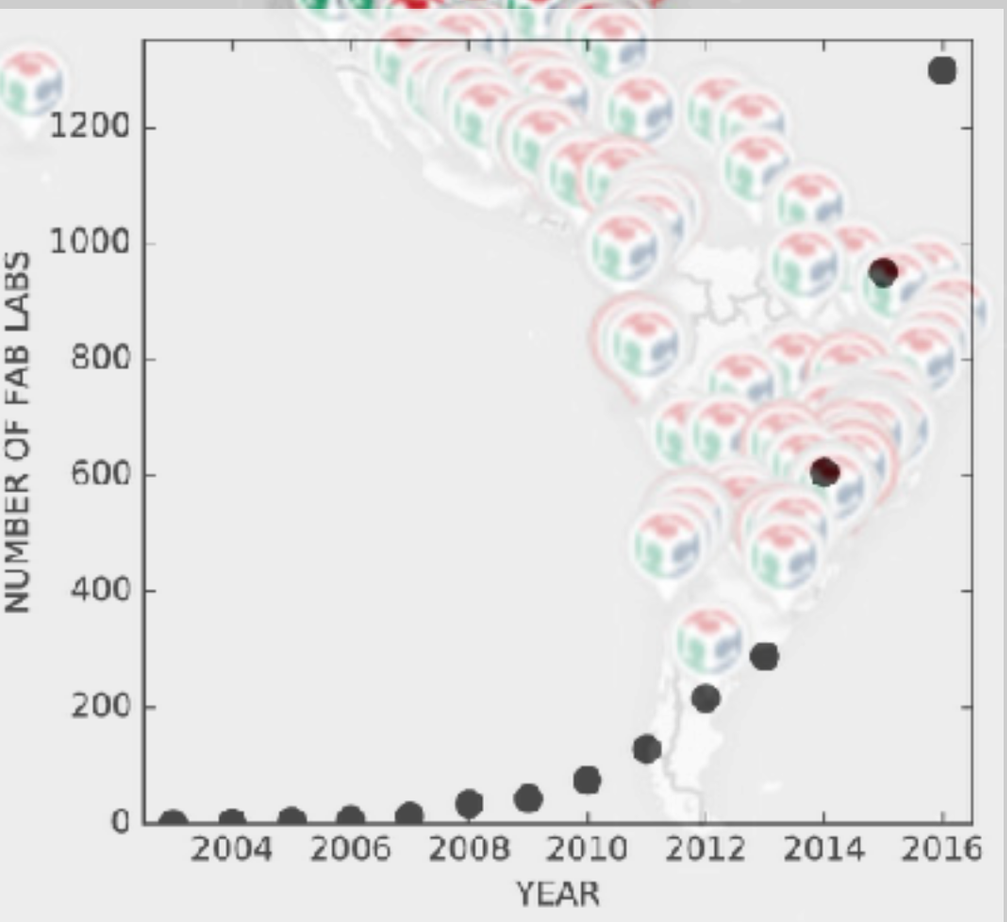
The Maker Movement

- Democratize invention
- Global, collective learning + doing
- DIY, reinvent, recycle
- Community can be local or virtual
- Open, shared solutions

Number of Fab Labs has doubled every year for the past 10 years…

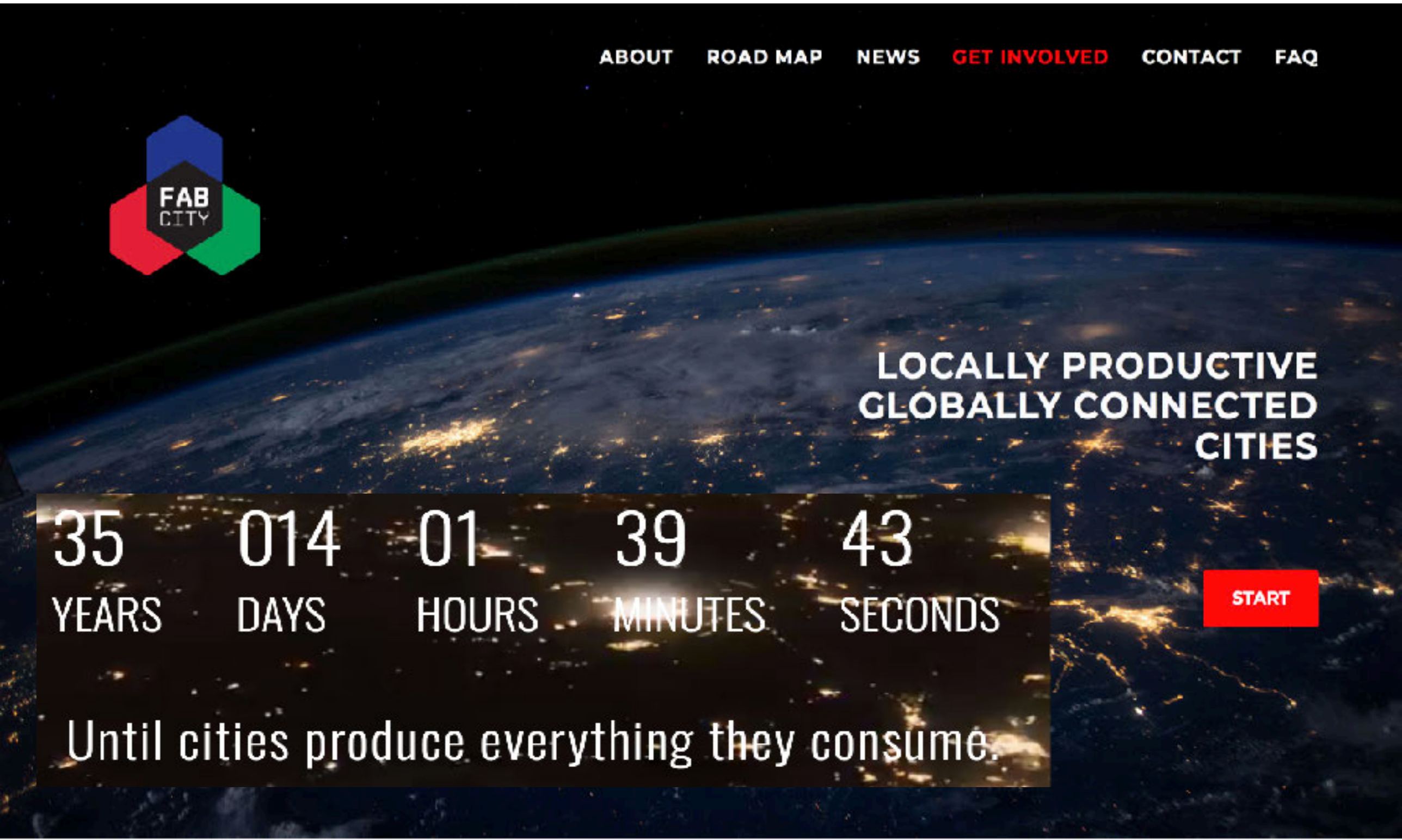


If this continues - there could be a million Fab Labs in the next decade



Defko Ap Niep Fab Lab Senegal

2054 Fab City Global Initiative

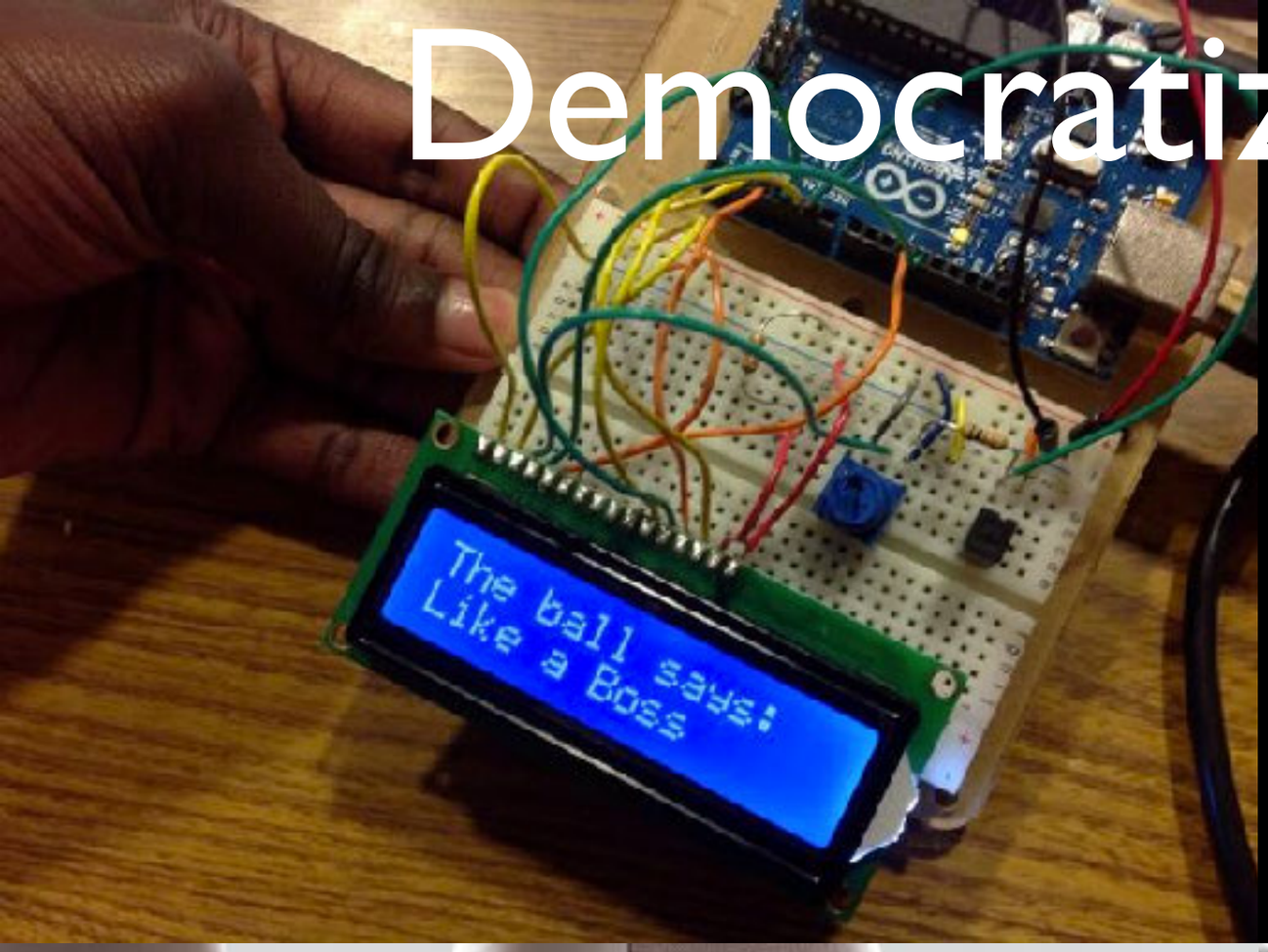


Shared approaches to digital manufacturing, energy rehabilitation, smart energy networks, electrical mobility, urban permaculture, intelligent infrastructure, and related policy and regulatory approaches.

MEMBER CITIES

Barcelona
Zagreb
Thimphu
Shenzhen
Georgia
Curitiba
Occitanie Region
Puebla
Mexico City
Auvergne-Rhône-Alpes
Amsterdam
Cambridge
Kerala
Sacramento
Belo-Horizonte
Ekurhuleni
Brest
Boston
Toulouse
Paris
Santiago
Velsen
Seoul
Oakland
Somerville
Detroit
Kamakura
Sorocaba

Democratizing Design



Making Sense

Advances and experiments in participatory sensing

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About powerful opportunities to make sense of the world

Not about tech skills

Not about jobs

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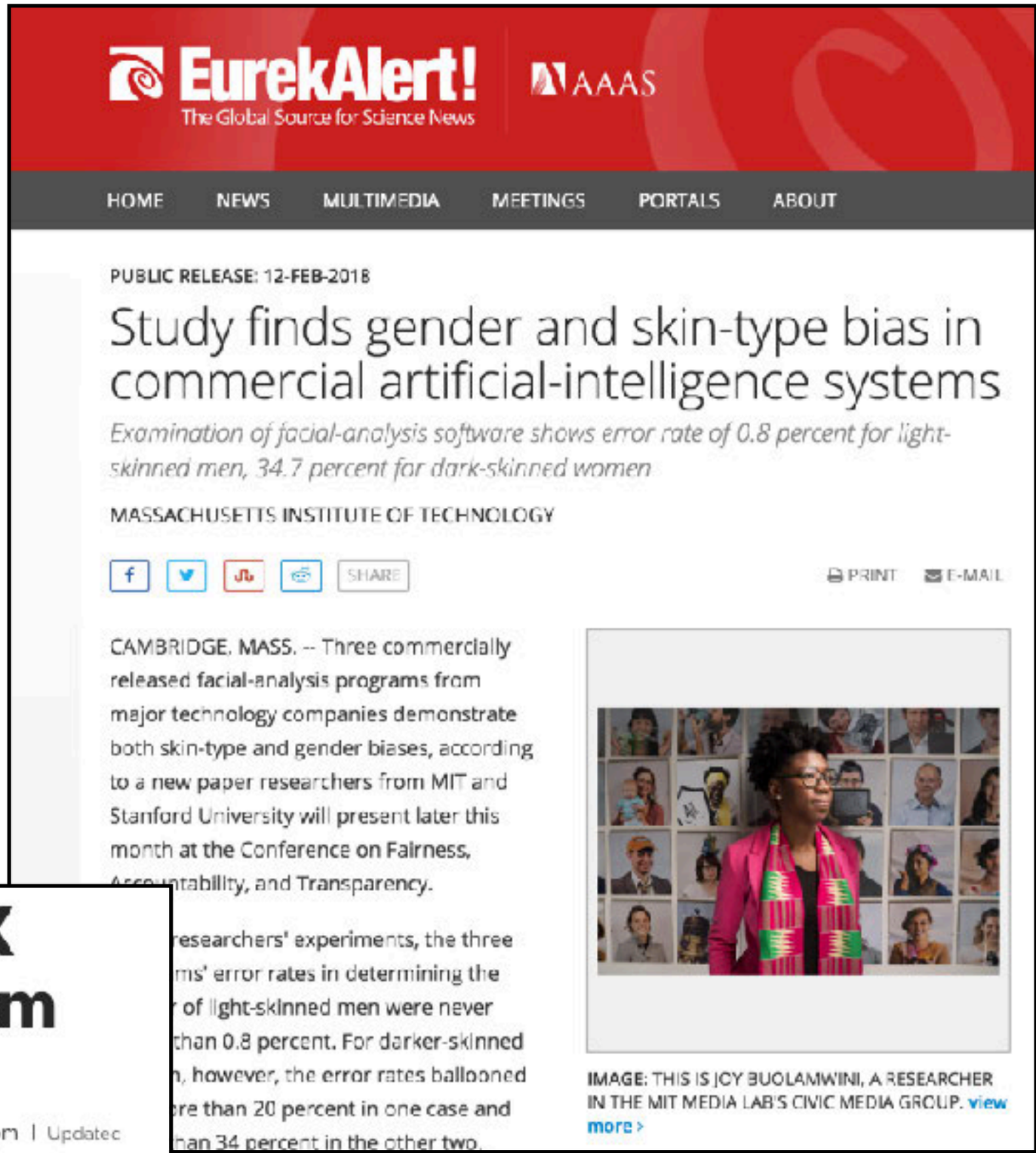
8 - Algorithm Bias & Ethics

- All algorithms have bias
- Lack of diversity in data pools
- Lack of diversity in people creating algorithms



Chinese users claim iPhone X face recognition can't tell them apart

By Guy Birchall, Tom Michael, The Sun

December 21, 2017 | 3:11pm | Updated

NEWS

Amazon shareholders to Jeff Bezos: Stop marketing facial recognition tool

THE THREAD

Amazon shareholders to Jeff Bezos: Stop marketing facial recognition tool

Privacy activists have sounded the alarm about the tool, called Rekognition.

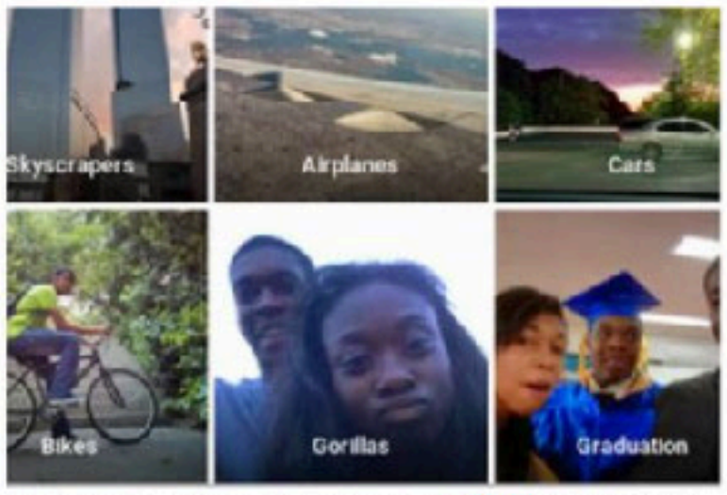
by Daniel Arkin / Jun. 18, 2018 / 8:50 AM ET

Google Mistakenly Tags Black People as 'Gorillas,' Showing Limits of Algorithms

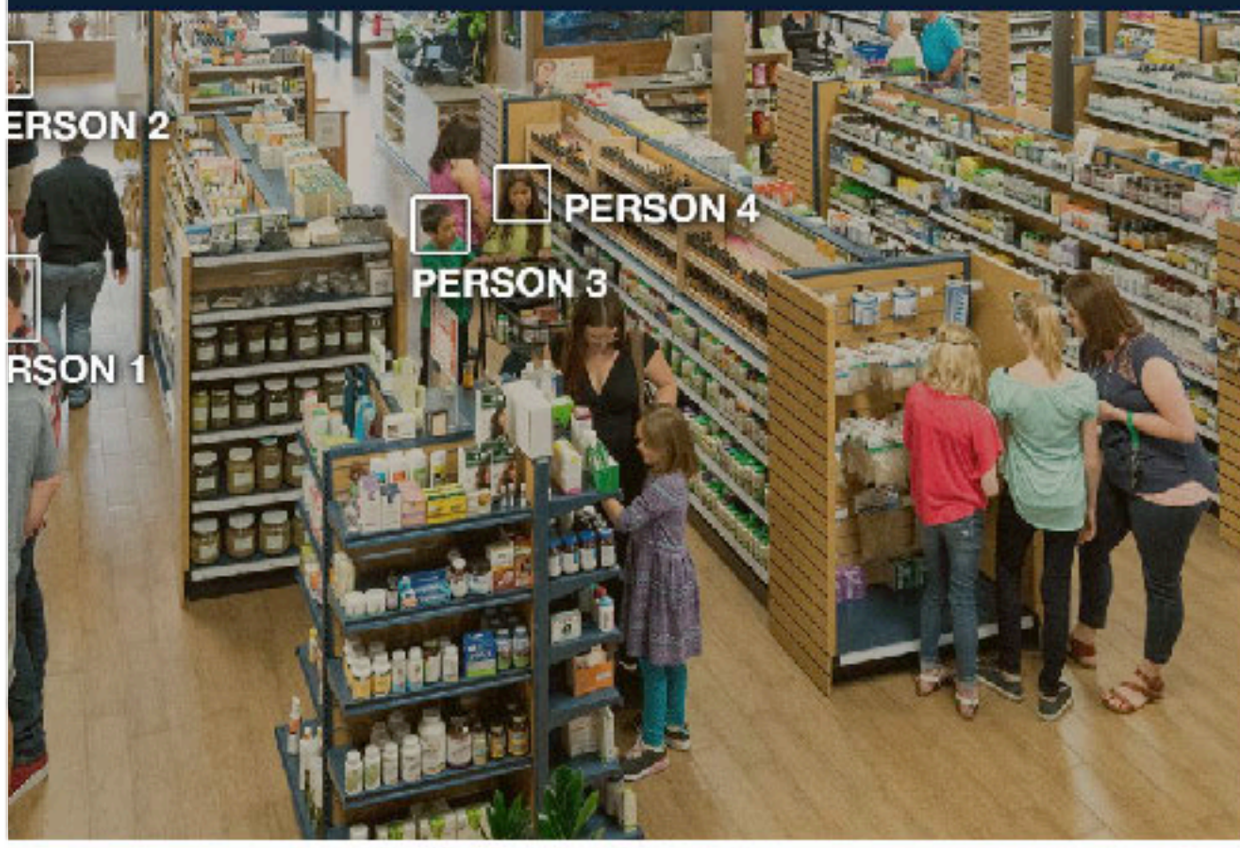
By Alistair Barr

Jul 1, 2015 3:40 pm ET

0 COMMENTS



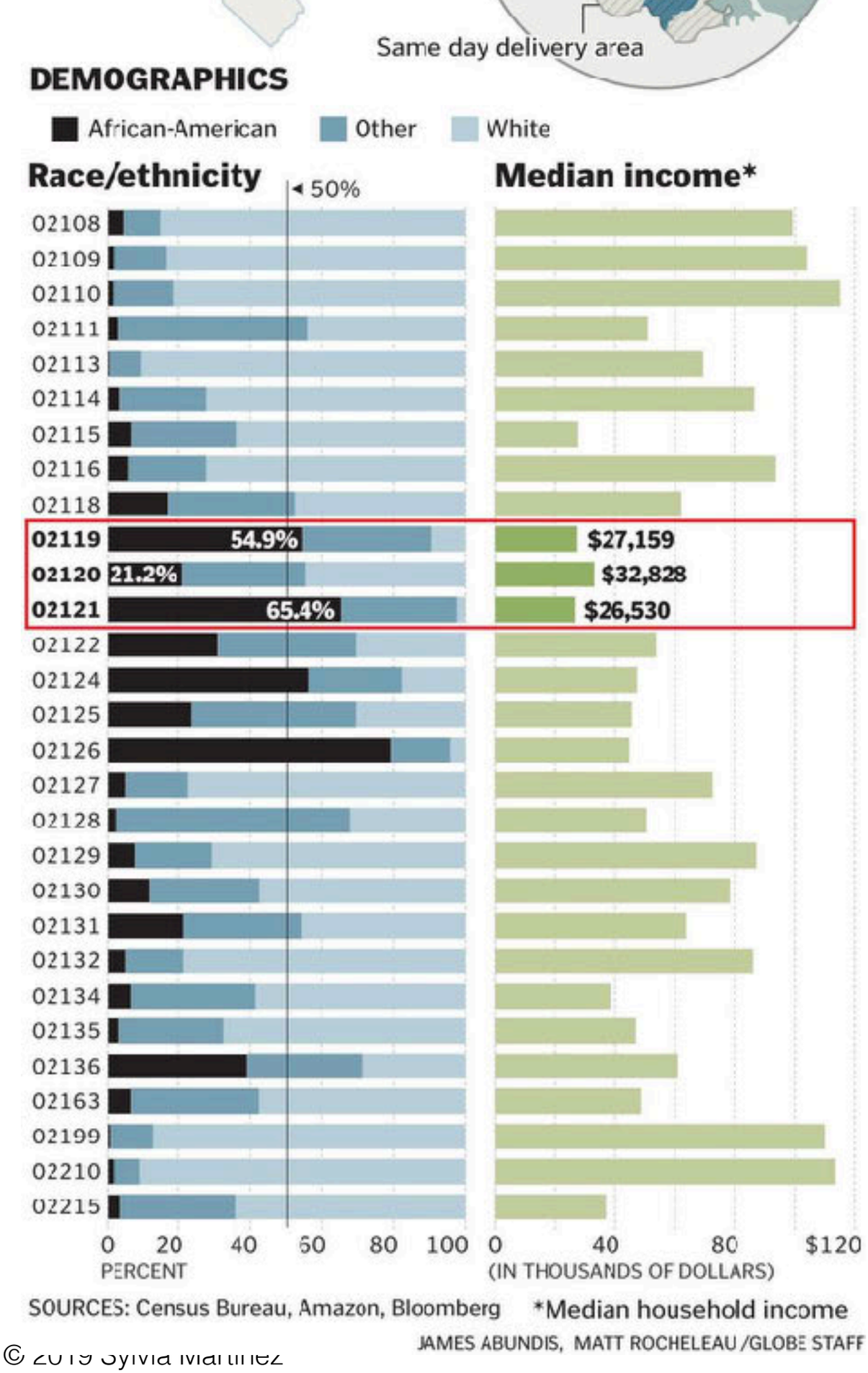
Black programmer Jacky Alciné said on Twitter that the new Google Photos app had tagged photos of him and a friend as gorillas. *JACKY ALCINÉ AND TWITTER*



Rekognition to analyze video, you can track people through a video even when their faces are not visible. Amazon

archolders are calling on the company to stop
gnition tool to local law enforcement agencies,
O Jeff Bezos that the technology could pose a

Google is a leader in artificial intelligence and machine learning. But the



Sub-prime service

The three Boston ZIP codes that do not receive Amazon Prime deliveries:

AI based on biased data sets create biased "intelligence"

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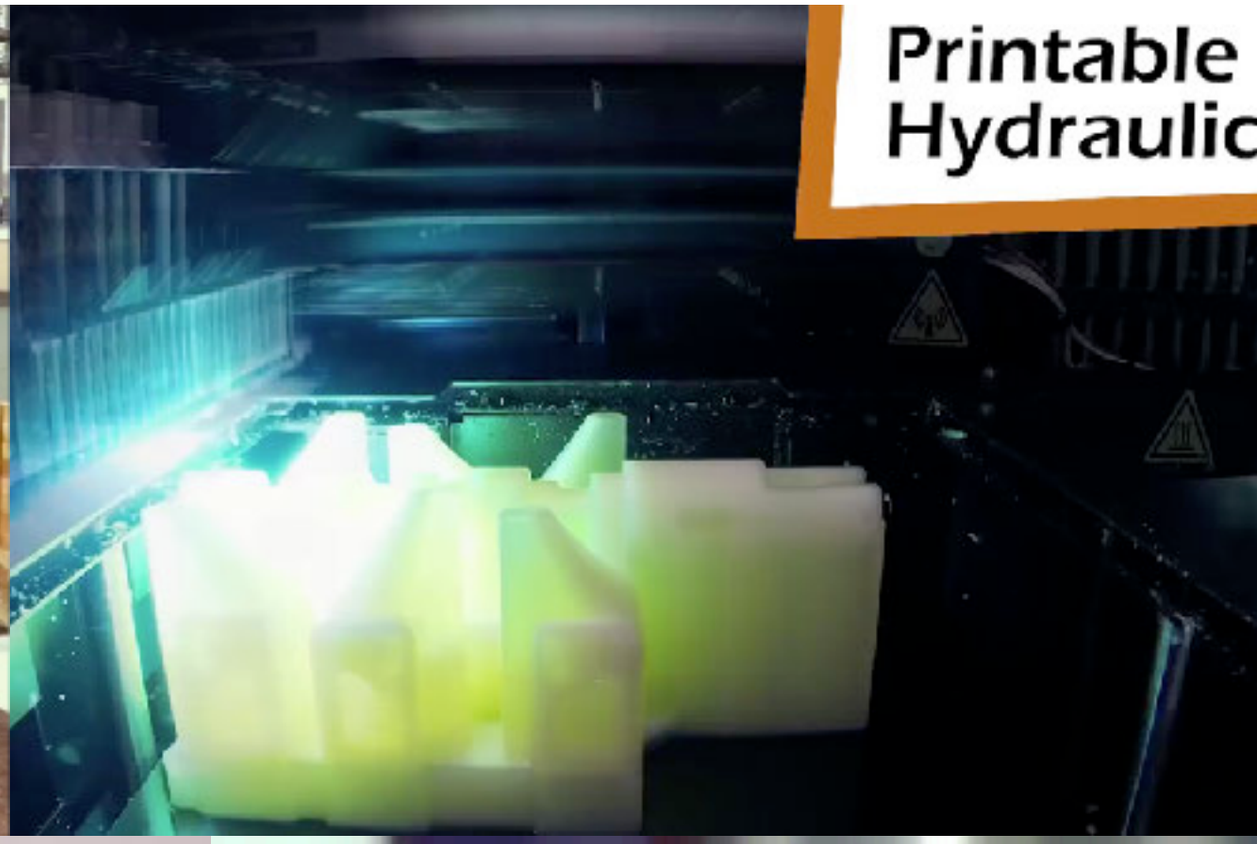
Ethics come from Empathy

9- Fabrication



Fabrication on the Space Station

Assembling a Self-Replicating Spacecraft

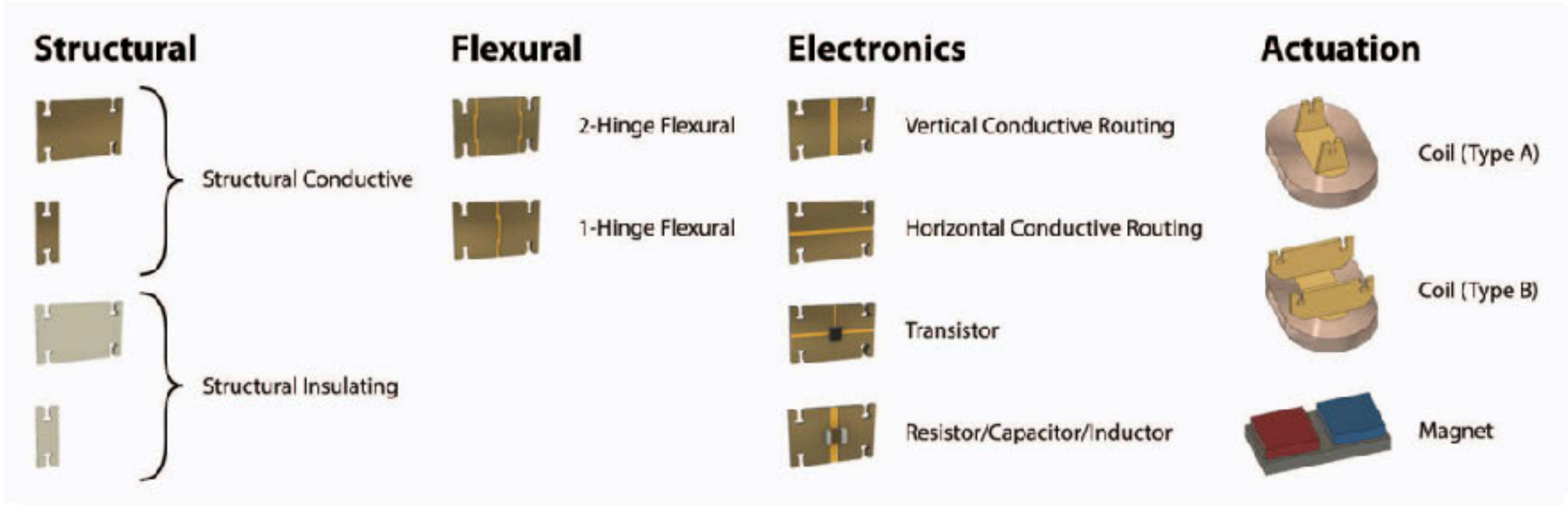
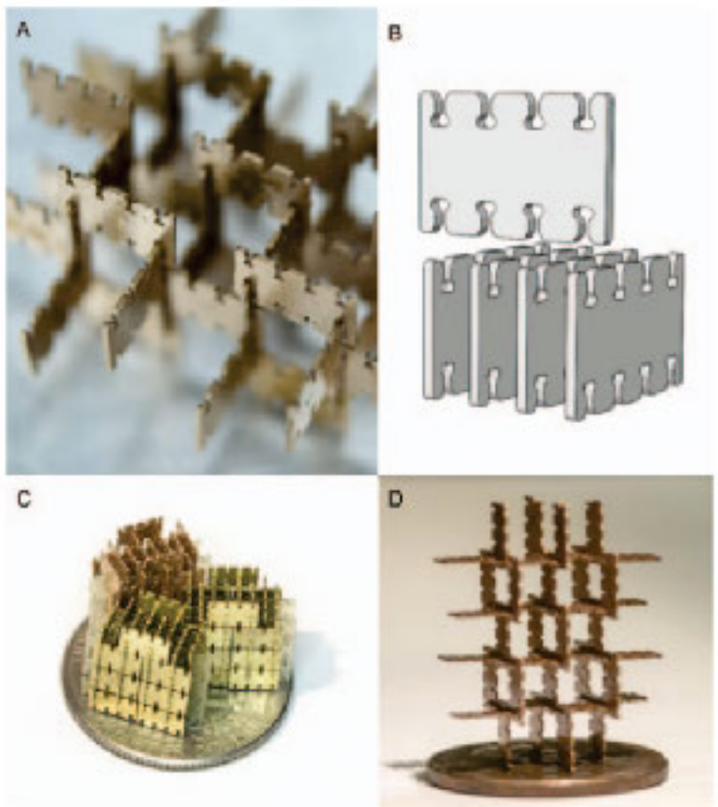


Figure 2. The part set. Thirteen part-types necessary to construct robotic functionality include: (Left to Right) structural parts that insulate and conduct, flexural parts with 1- or 2- degrees of freedom, electronic parts that switch and route signals, and actuation parts including coils and magnets.



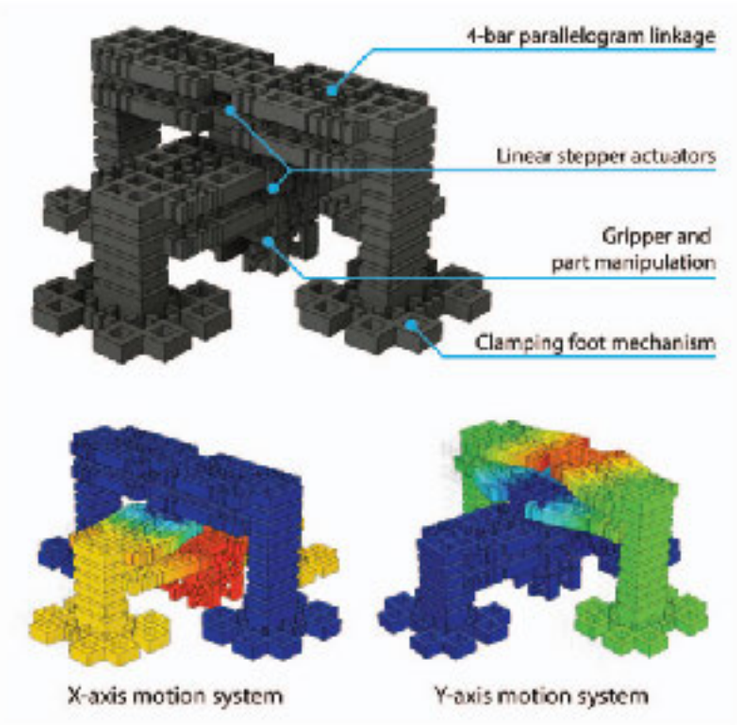


Figure 3. The assembler is assembled from a number of

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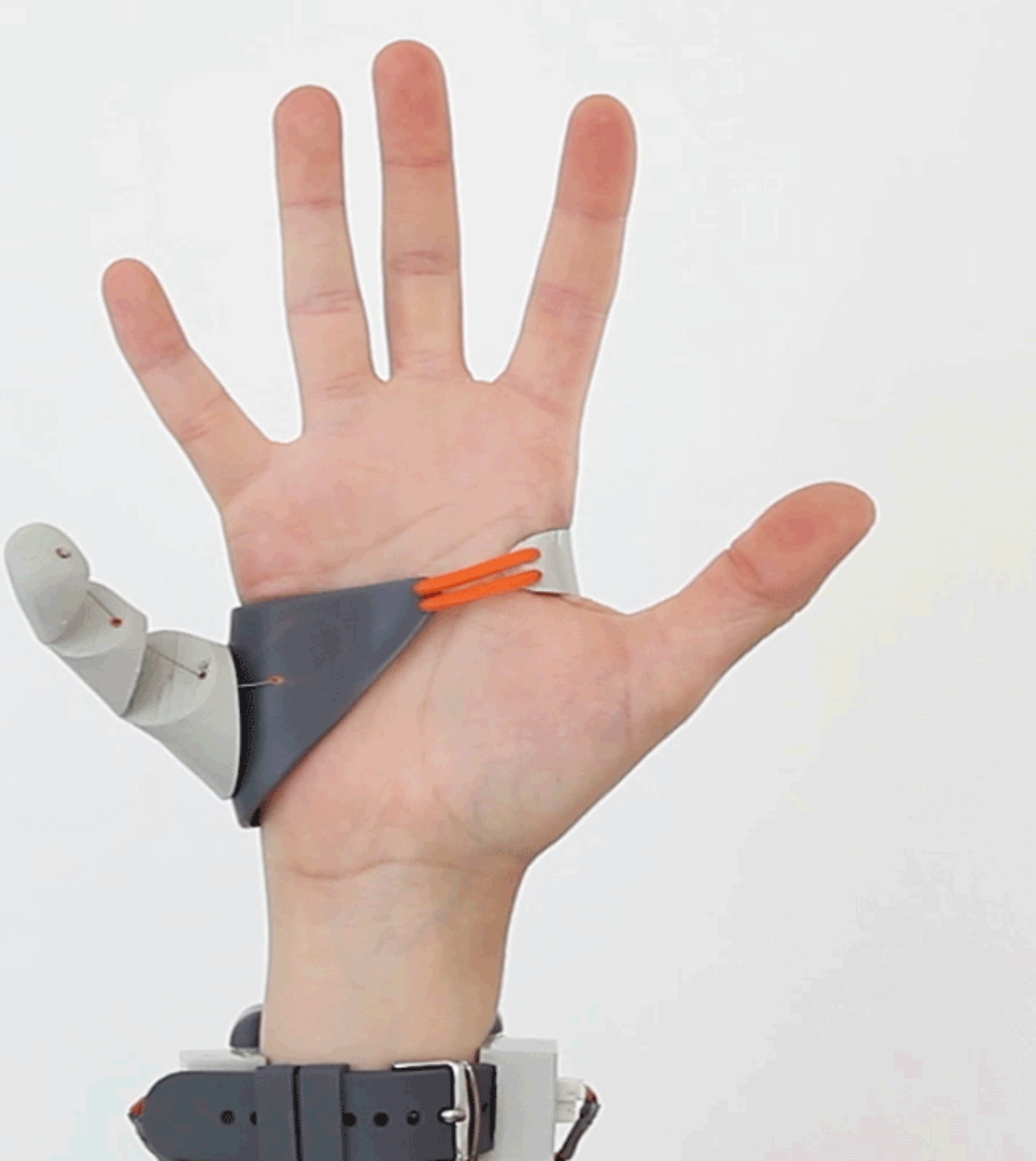

We Know….

- Fabrication devices will get better, faster, cheaper, smaller/larger
- Cutters, CNC machines, routers, mills
- Features will converge (4 in 1)
- New materials (PLA blends - metal, wood, algae, glow in the dark, water soluble)
- New techniques will surpass melted plastic (resin, lasers, powder)
- Design software will get better

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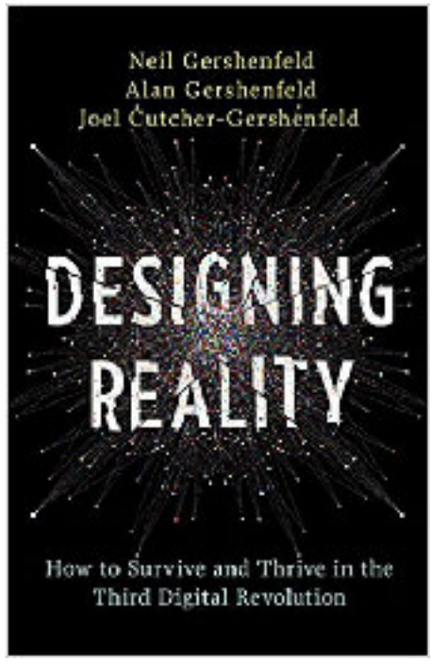
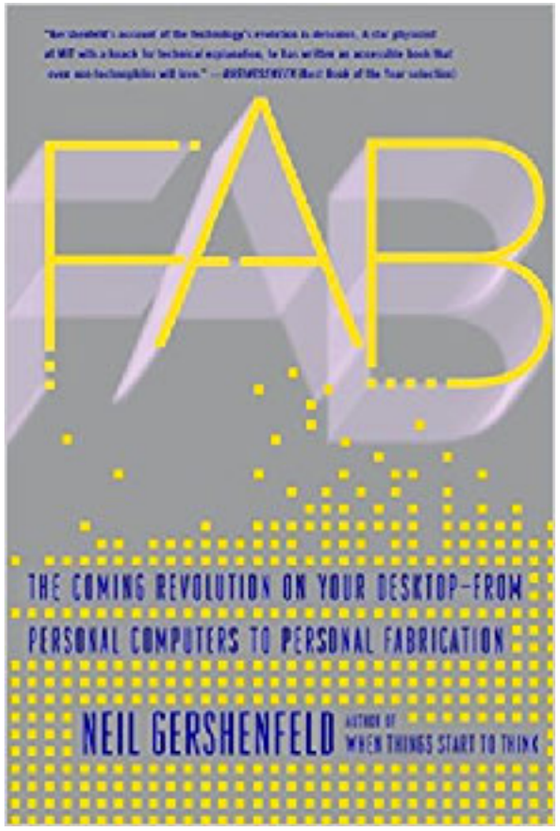
Neil Gershenfeld
Center for Bits and Atoms

- First digital revolution programmable bits
- Second digital revolution programable manufacturing
- Third digital revolution programable materials





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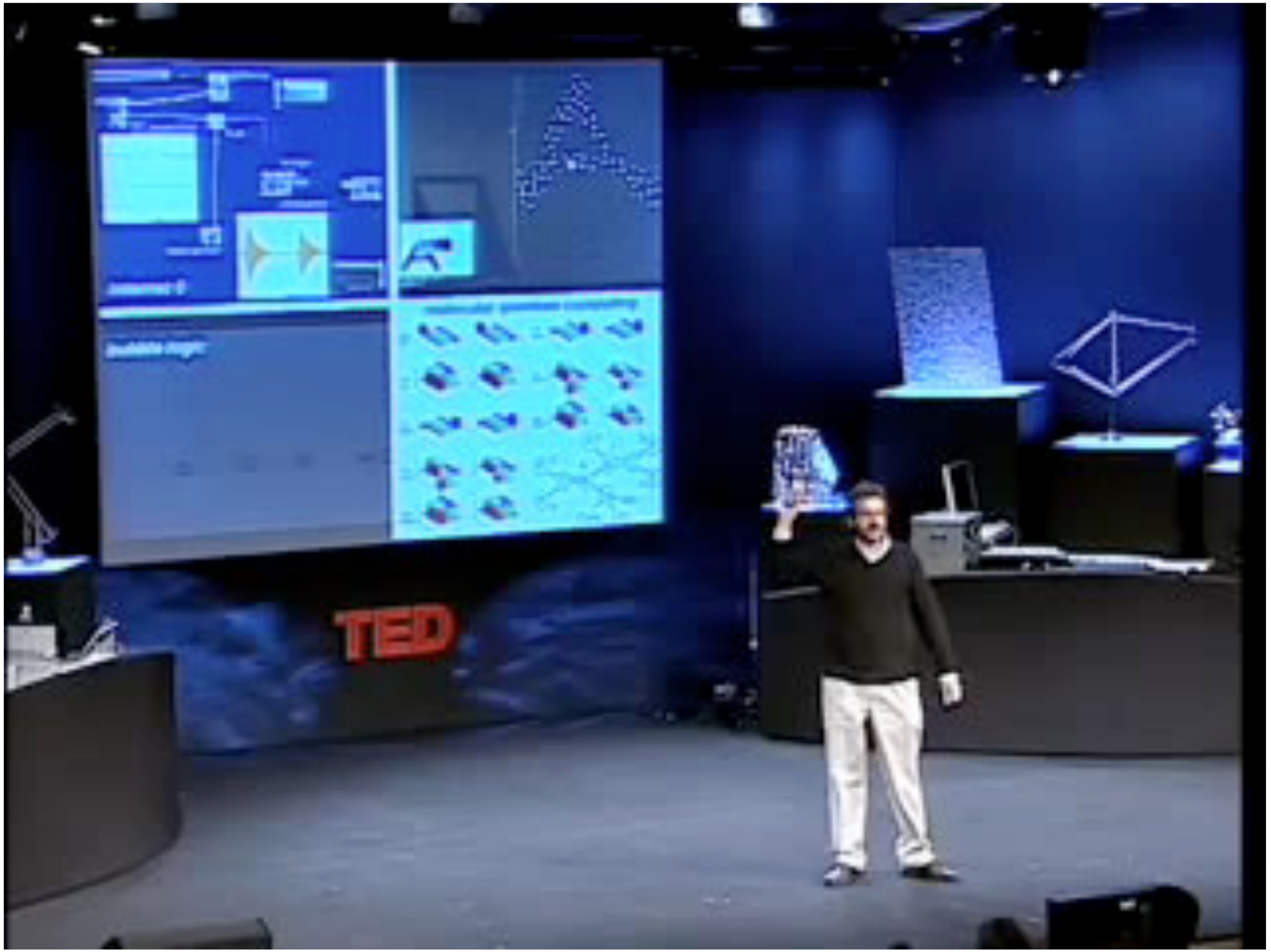

Neil Gershenfeld - “Compute to fabricate” where the output of a program “rearranges atoms as well as bits”

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10 - Don’t forget the M

- We have a problem with math
- School math is too focused on calculation
- Least changed of all ancient subjects

We spend 106 million lifetimes a day teaching hand calculation to people - what computers do best.
- Conrad Wolfram

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WolframAlpha computational knowledge engine

31 inches per second

Examples Random

Input interpretation:

31 in/s (inches per second)

Unit conversions: More

787.4 mm/s (millimeters per second)

0.7874 m/s (meters per second)

1.761 mph (miles per hour)

2.835 km/h (kilometers per hour)

2.583 ft/s (feet per second)

Comparison as speed:

≈ 0.7 × typical human walking speed (≈ 2.5 mph)

Interpretations: More

speed

Basic unit dimensions:

$[\text{length}]\,[\text{time}]^{-1}$

Corresponding quantities:

Time to travel 1 meter from $t = d/v$:

1.3 seconds

0.021 minutes

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wolframalpha.com

sylviamartinez.com

“Pick any field “X,” from archaeology to zoology. There either is now a “computational X”, or there soon will be. Doctors, lawyers, teachers, farmers, whatever—the future of all these professions will be full of computational thinking. ”
- Stephan Wolfram

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WolframAlpha.com WolframCloud.com All Sites & Public Resources...

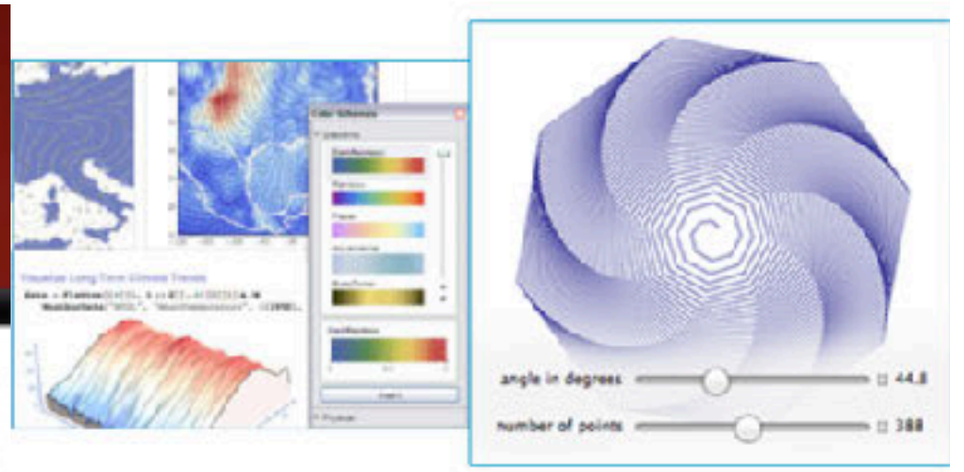
WOLFRAM
COMPUTATION MEETS KNOWLEDGE

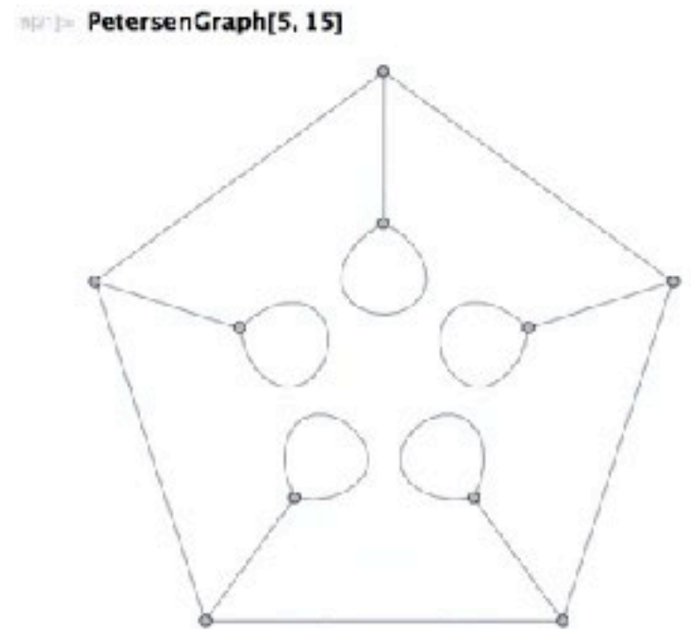
Products & Services Technologies Solutions Support & Learning Company Search

WOLFRAM FOR EDUCATION ›

WOLFRAM TECHNOLOGY SYSTEM
FOR HIGH SCHOOLS

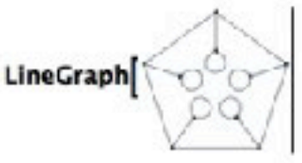
Enrich your school and engage your students with the latest learning technology





Computable Document Format™

Today's online documents are like yesterday's paper—flat, lifeless, inactive. Instead, CDF puts easy-to-author interactivity at its core, empowering readers to drive content and generate results live.



Used in all top 200 universities worldwide, the latest Wolfra now also cover high school.

Bring a subject to life with compelling on-the-fly visualizations backed by powerful student-accessible computation and data capabilities. Create lesson plans that mix text, graphics, code, and more. Let your students self-test with automatic problem generation—and get tutor-quality step-by-step solutions. And use the breakthrough Wolfram Language to introduce students to the power of modern computation—and enable

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Prime Difference Sequences and Cellular Automata

Exploring possible interfaces between primes (analytic number theory) and the space of CA rulesets.

June 23, 2017—Daniel Reynolds

What Does It Look Like When We Visualize the Spacing between Consecutive Prime Numbers?

When looking at prime numbers, one of the distinctive patterns is the spacing between consecutive primes. In order to get the spacing, we can write a function that takes the differences between n consecutive primes in a nested list corresponding to a finite difference table of absolute differences.

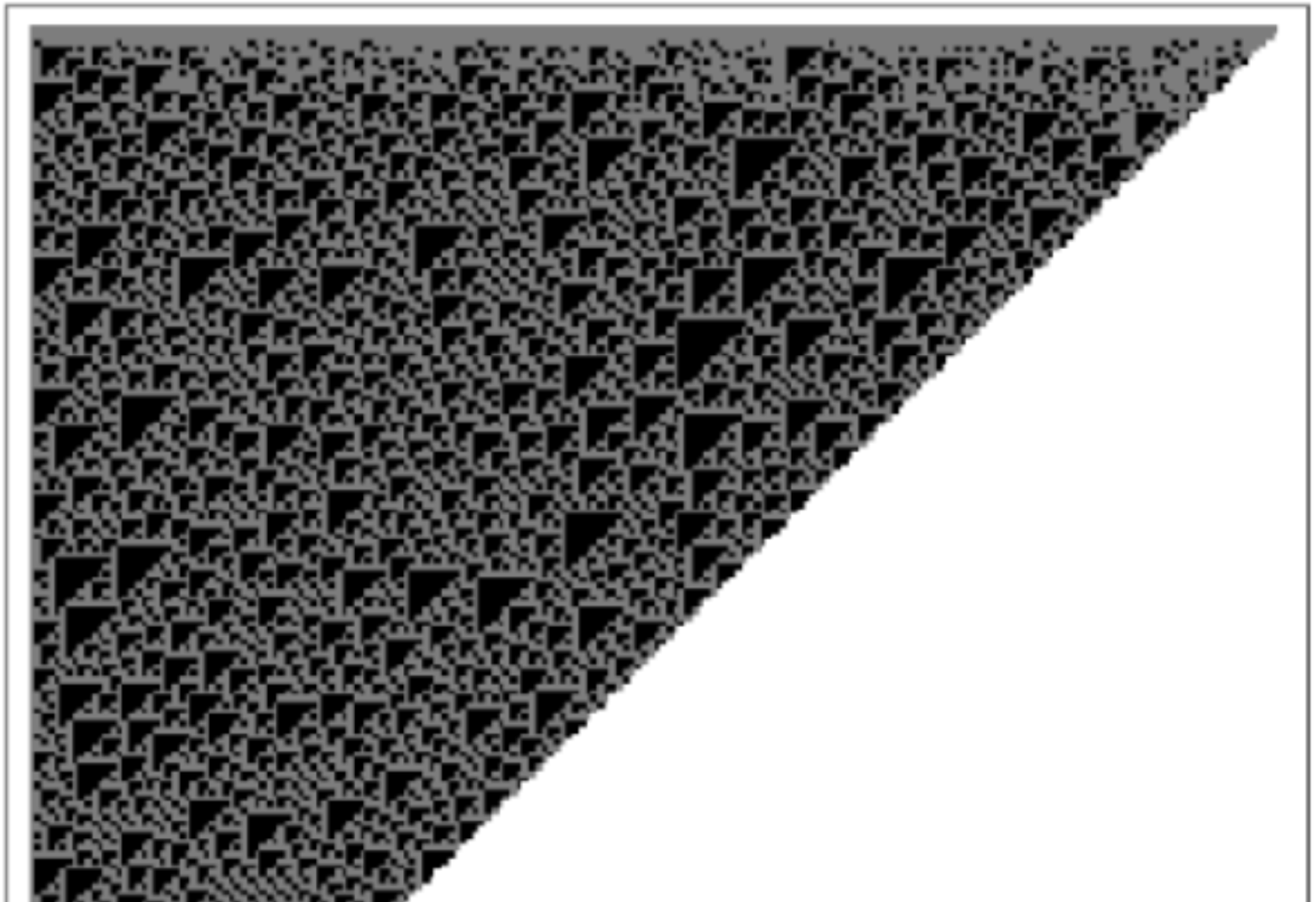
```
In[ ]:= PrimeDifferences[n_] := NestList[Abs[Differences[#]] &, Table[Prime[i], {i, 1, n}], n - 1]
```

Now we can look at one of these nested lists for the first 25 primes. Just looking at the raw data, we see that after a certain number of steps, all the data turns to being only 2s and 0s except for a constant 1 at the start of each list step.

```
In[ ]:= example1 = PrimeDifferences[25]
```

Computational Essay

(topics from Wolfram Summer School)



Fields & Departments

Wolfram technologies provide an integrated approach to computation across the curriculum.

Art, Design & Music

Let your students create cutting-edge interactive visual art, algorithmic music, and 3D printouts—learning geometric layout and modeling, image manipulation, color theory, and music theory—as well as computer skills.

Business

Give your students instant access to a wealth of real-world financial and other data—and illustrate business concepts with compelling interactive models and visualizations, reinforcing quantitative and computing skills.

Chemistry

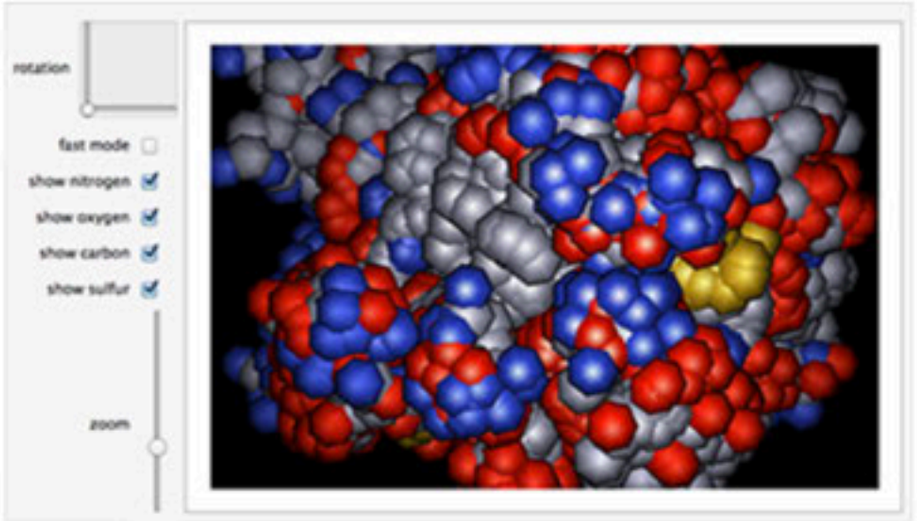
With vast built-in chemical databases, instantly visualize 3D molecular structures—and generate automatic step-by-step solutions to chemistry problems and analyze experimental measurements.

Earth Science

Weather, earthquakes, minerals, astronomy, geography: Wolfram tools give you deep and up-to-the-minute data—connected to instant compelling visualizations.

Biology

Illustrate principles of biology with real-world data and compelling interactive models and visualizations—and give your classes a streamlined way to collect and analyze data.



Computer Science

Introduce programming in a uniquely easy and compelling way with the breakthrough Wolfram Language—with instant visualizations and built-in real-world data—and make connections across the curriculum.

Economics

Use a wealth of real-world data to demonstrate principles of economics, with instant interactive modeling and

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Industrial Technology

Design

Materials Science

Material Ecology

Fabrication

Synthetic Biology

Robotics

VR & AR

Maker movement

AI

DIY Culture

Internet

Ethics

Reuse-recyle

Networks

Global Awareness

STEAM

Action

Aesthetics

Agency

Design

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STEAM

A is the verb

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What's Next

- Learning from millions of years of evolution
- Convergence, Disintermediation, Democratization, DIY
- Ethics to the forefront
- Exponential - just when you think nothing is happening…
- When you hear "it takes too long", "it's too expensive" or "why would anyone want that?" *they are wrong!*

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What's Next *for School*

- When will the curriculum change?
- Making expanding to all STEAM subjects
- Design as a comprehensive topic K-12
- Preparing students to dealing with exponential change

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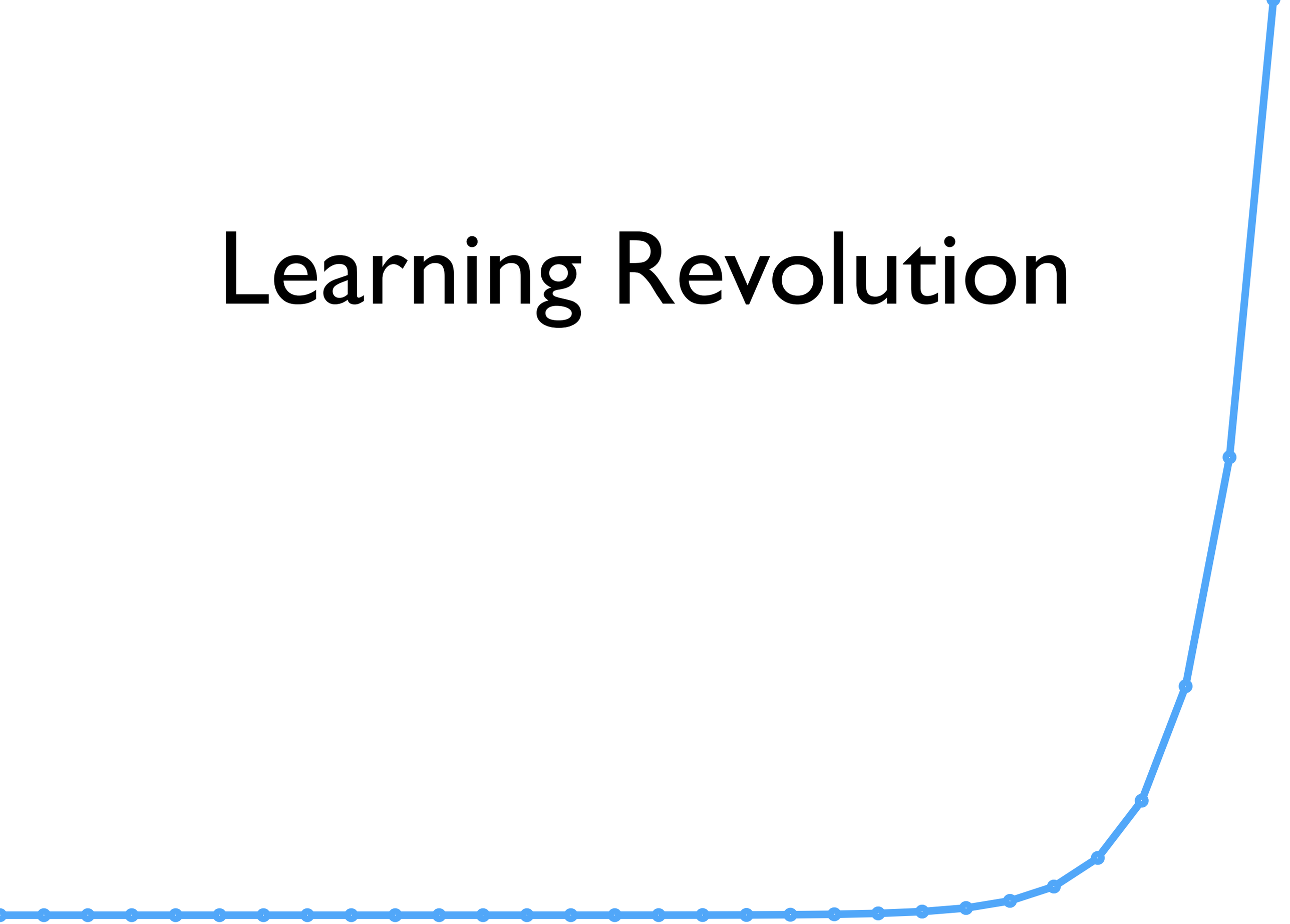
Learning Revolution



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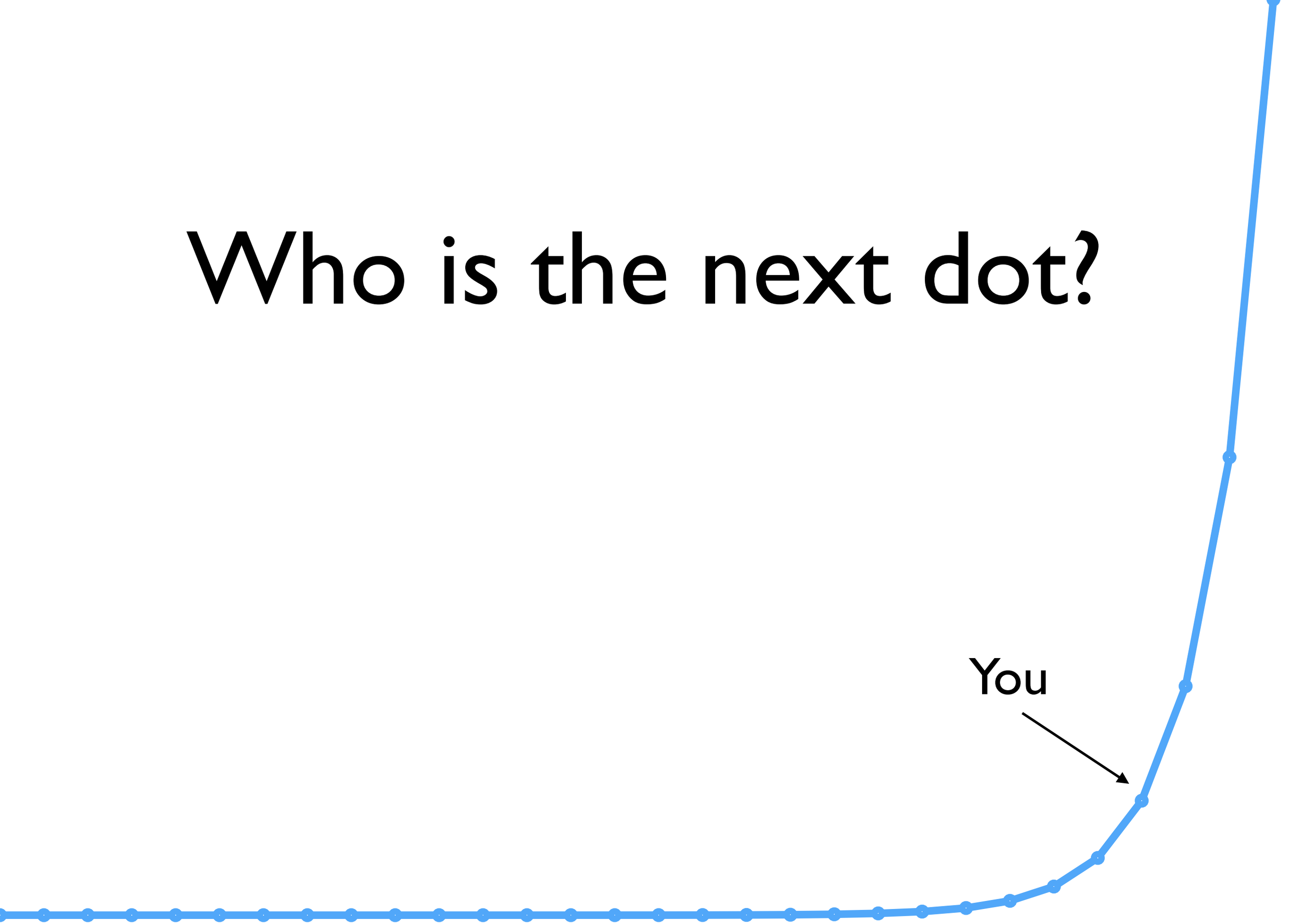
Who is the next dot?



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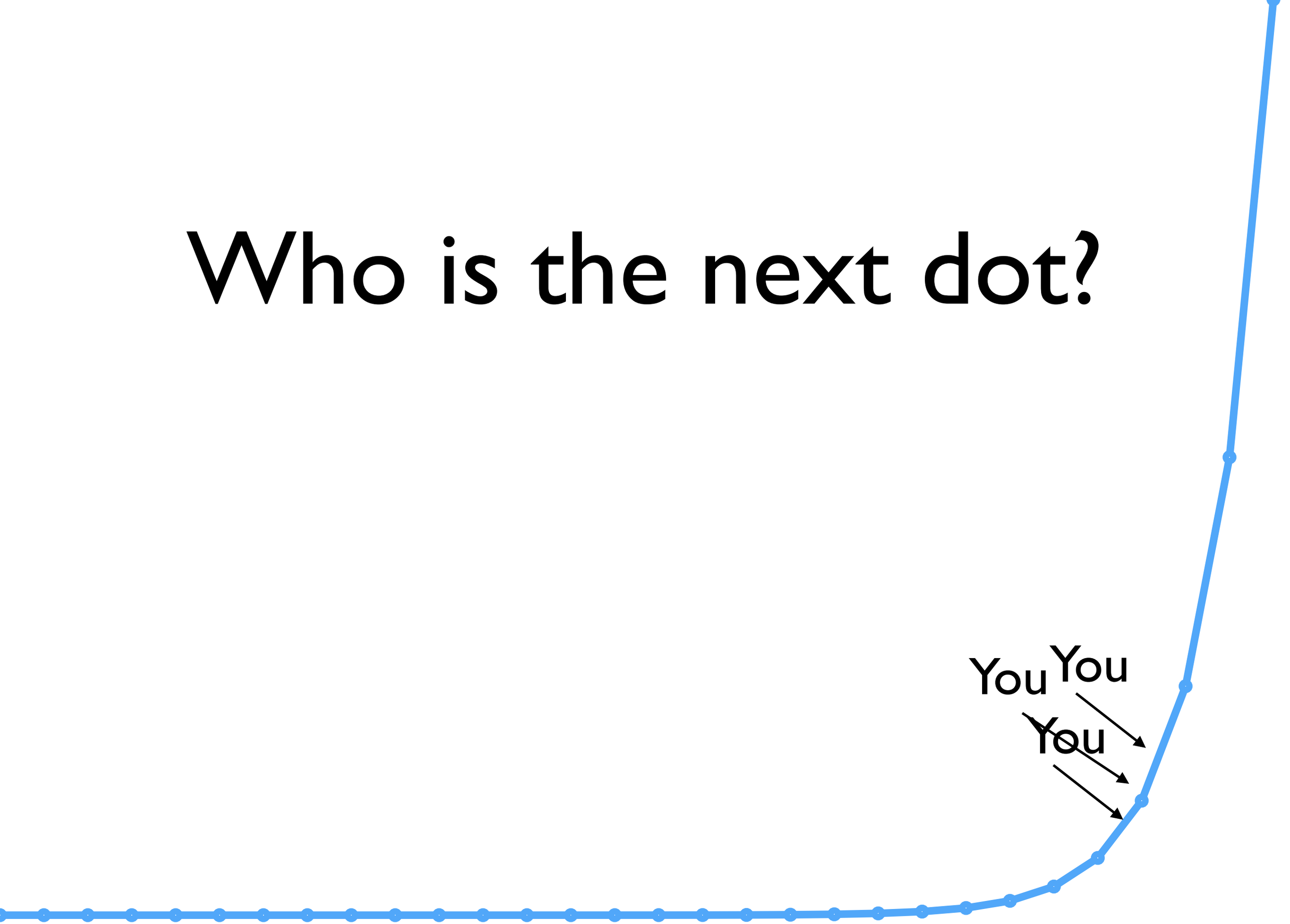

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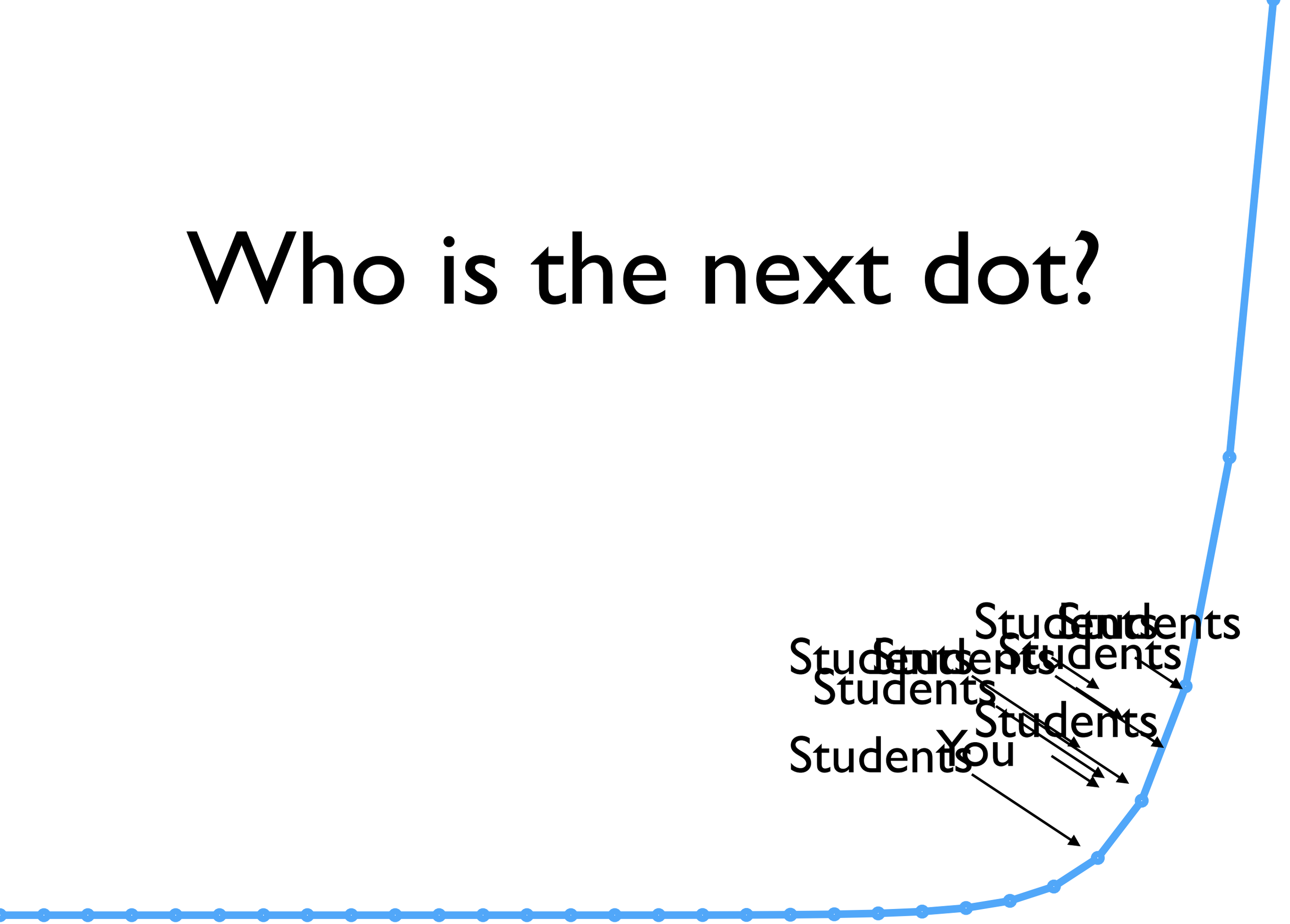

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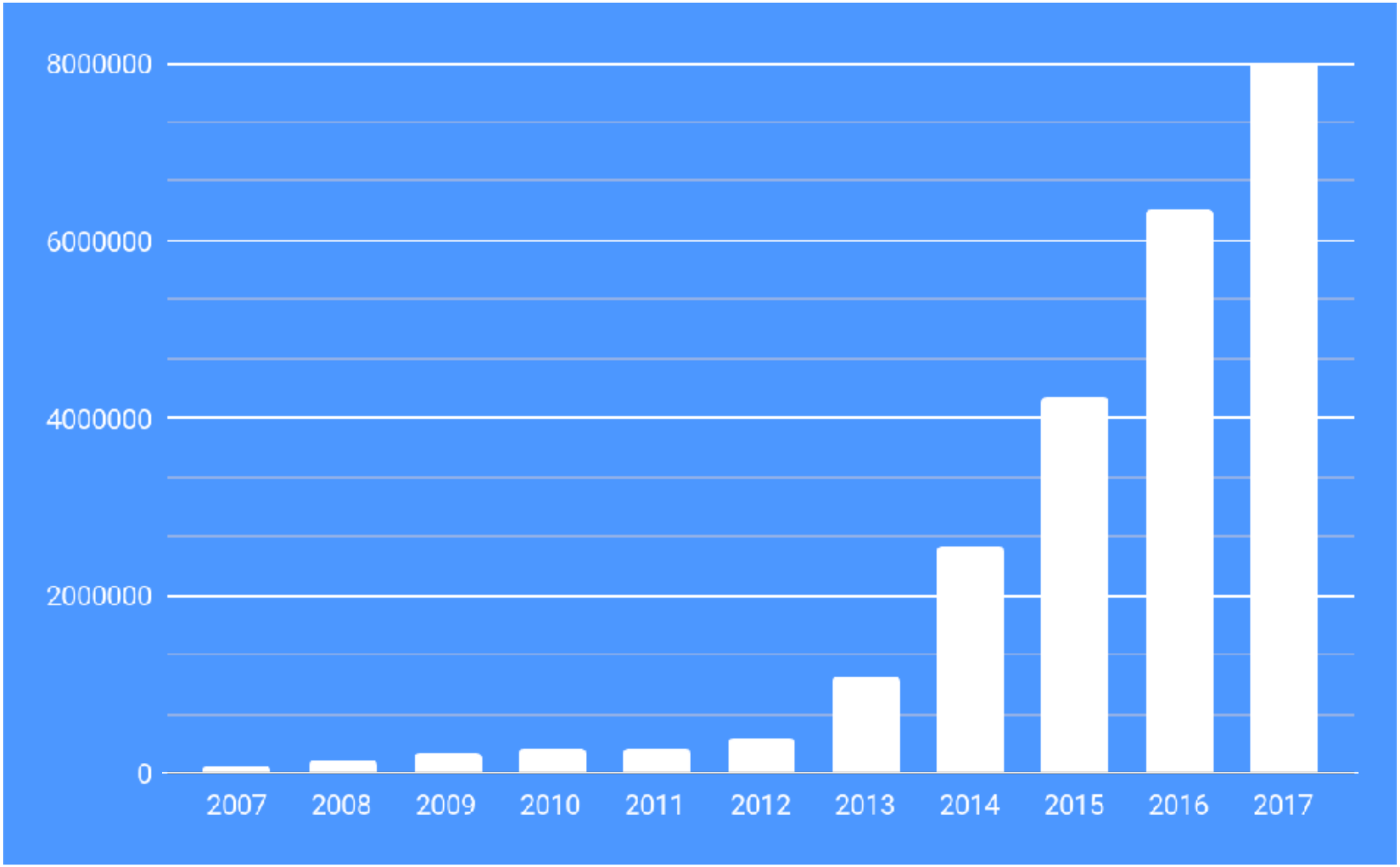
Kid Power - Children joining Scratch each year



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Learning Revolution through Massive Inclusion

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Seize this moment in history to give kids the mindset, tools, and techniques to ***make sense*** and ***take charge*** of their world.

Where educators invent the future!

Constructing Modern Knowledge

July 15-19, 2019 ***Manchester, NH USA***

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Books from CMK Press cmkpress.com

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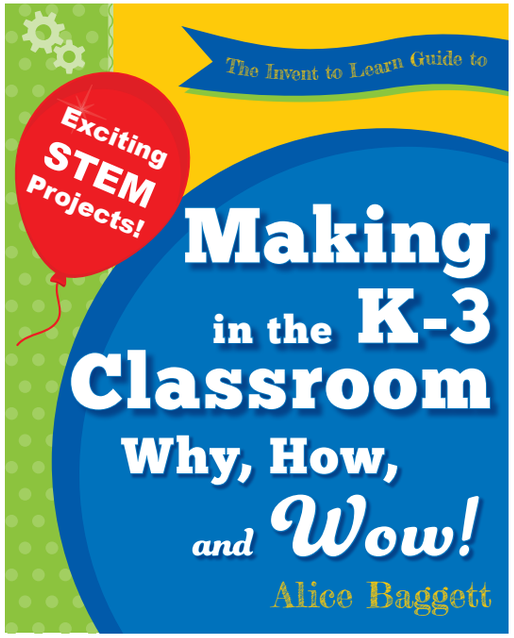

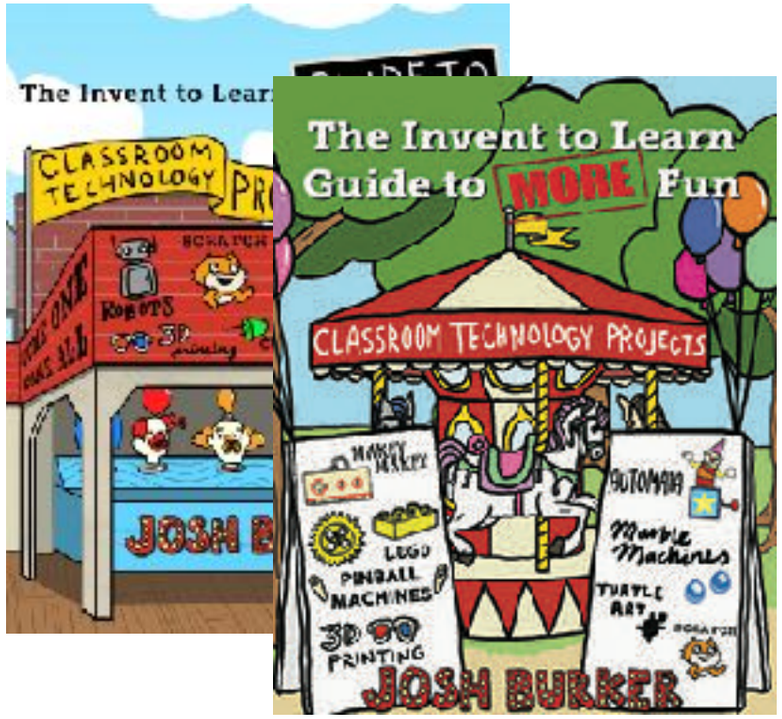

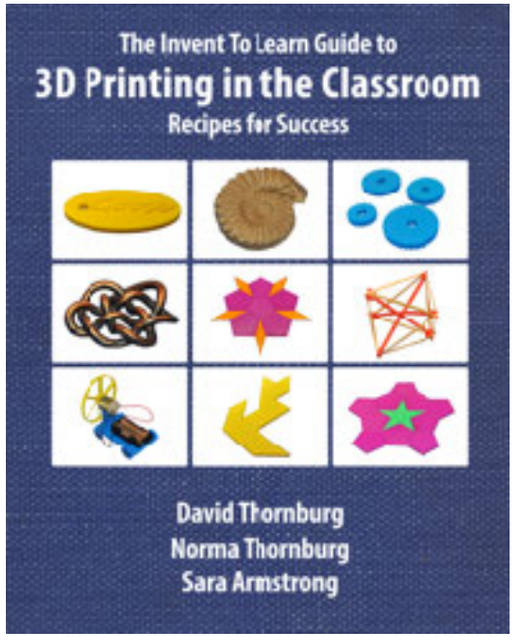

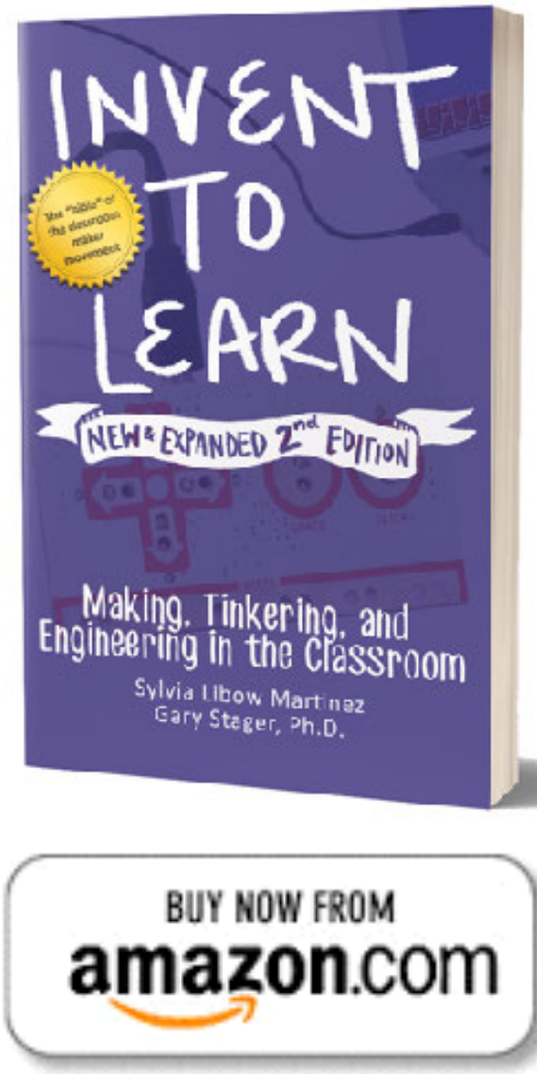

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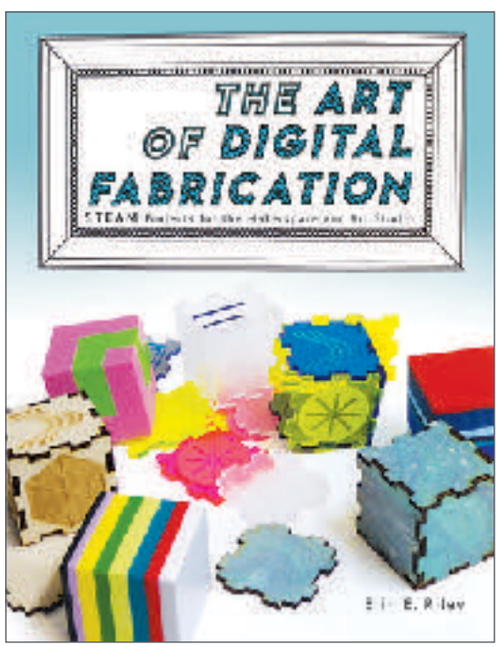

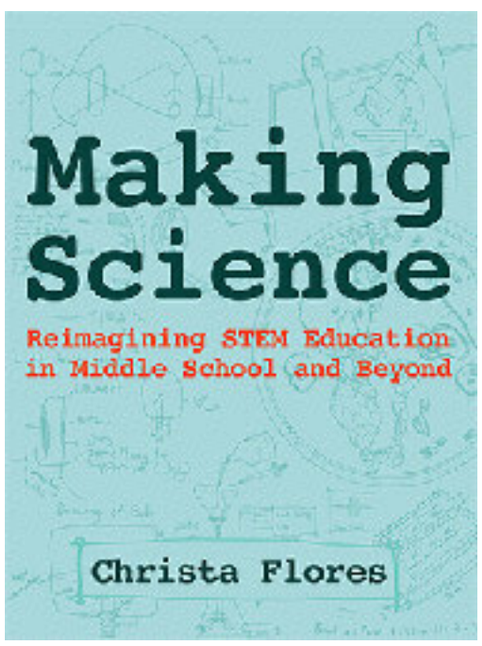

Full STEAM ahead!

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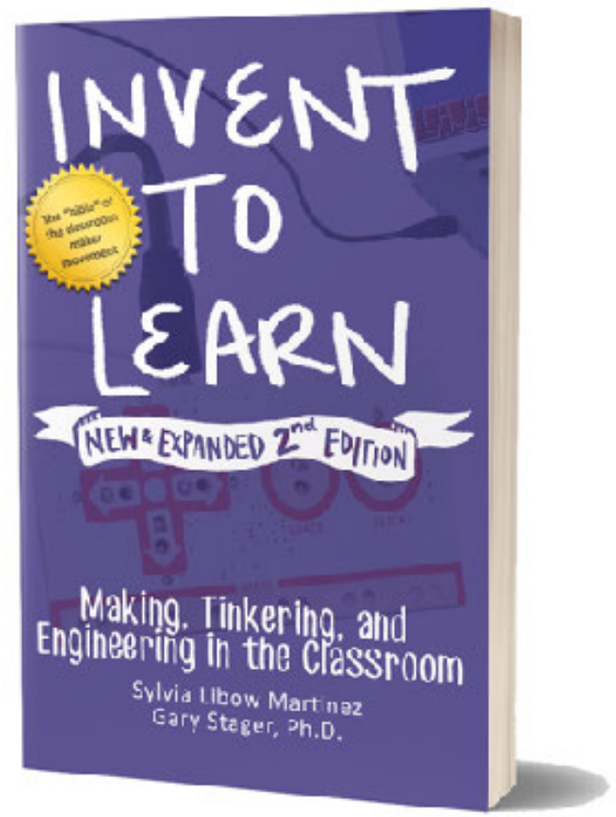
sylviamartinez.com



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