~2005

Seu Jorge (born June 8, 1970; Portuguese pronunciation: ['sew 'ʒɔʁʒi]) is a Brazilian musician, singer/songwriter and actor. Born Jorge Mário da Silva, he was raised in the city of Belford Roxo, near Rio de Janeiro. When he was 19, he became homeless and remained homeless for three years; nonetheless, his musical talent flourished when he was living in the streets and he became known in the favelas.

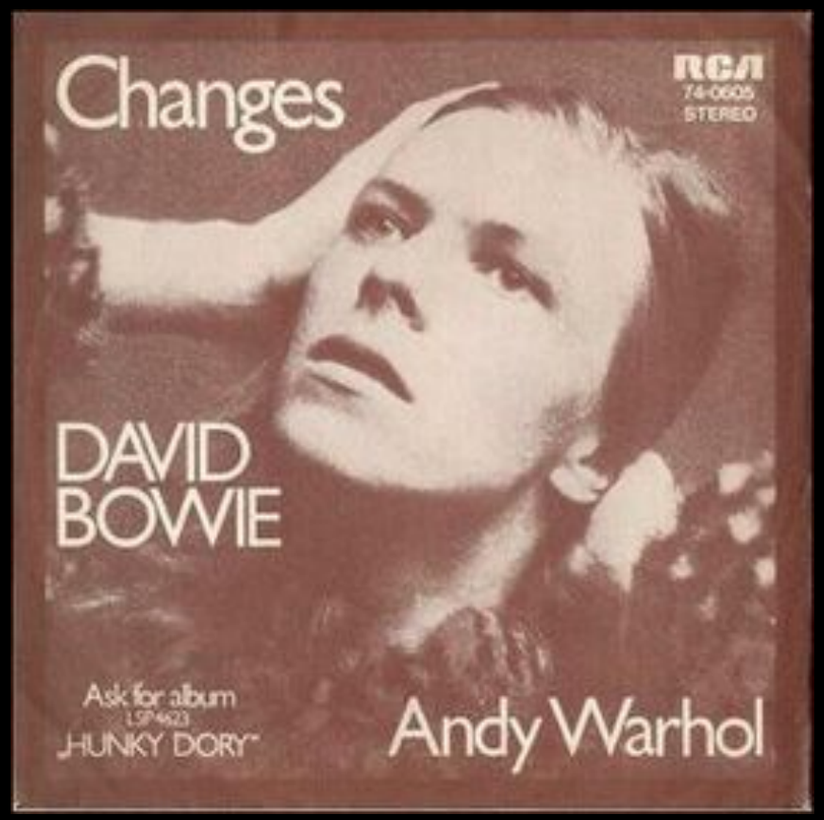
https://en.wikipedia.org/wiki/Seu_Jorge

https://youtu.be/UvhGvxuOREw

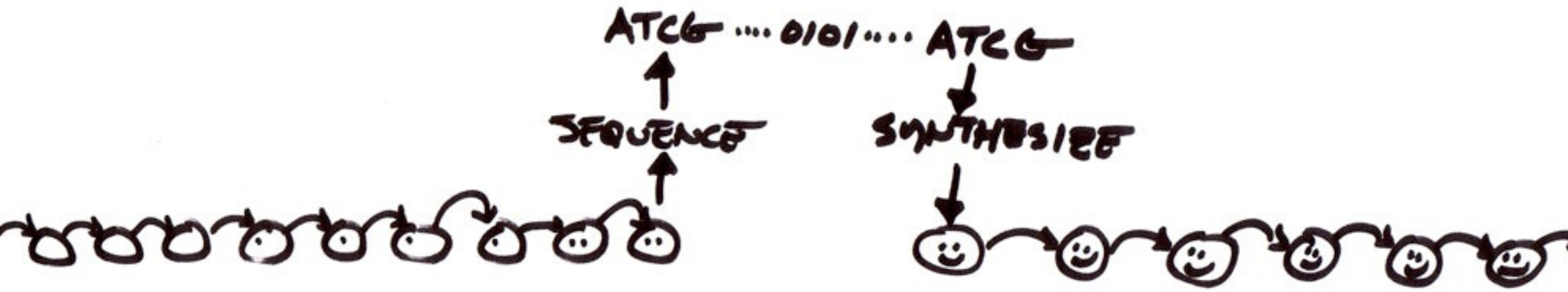
~1971

"**Changes**" is a song by David Bowie, originally released on the album *Hunky Dory* in December 1971 and as a single on January 7, 1972, the day before Bowie's 25th birthday. Despite missing the Billboard top 40, "Changes" became one of Bowie's best-known songs. The lyrics are often seen as a manifesto for his chameleonic personality, the frequent change of the world today, and frequent reinventions of his musical style throughout the 1970s.

https://en.wikipedia.org/wiki/Changes_(David_Bowie_song)



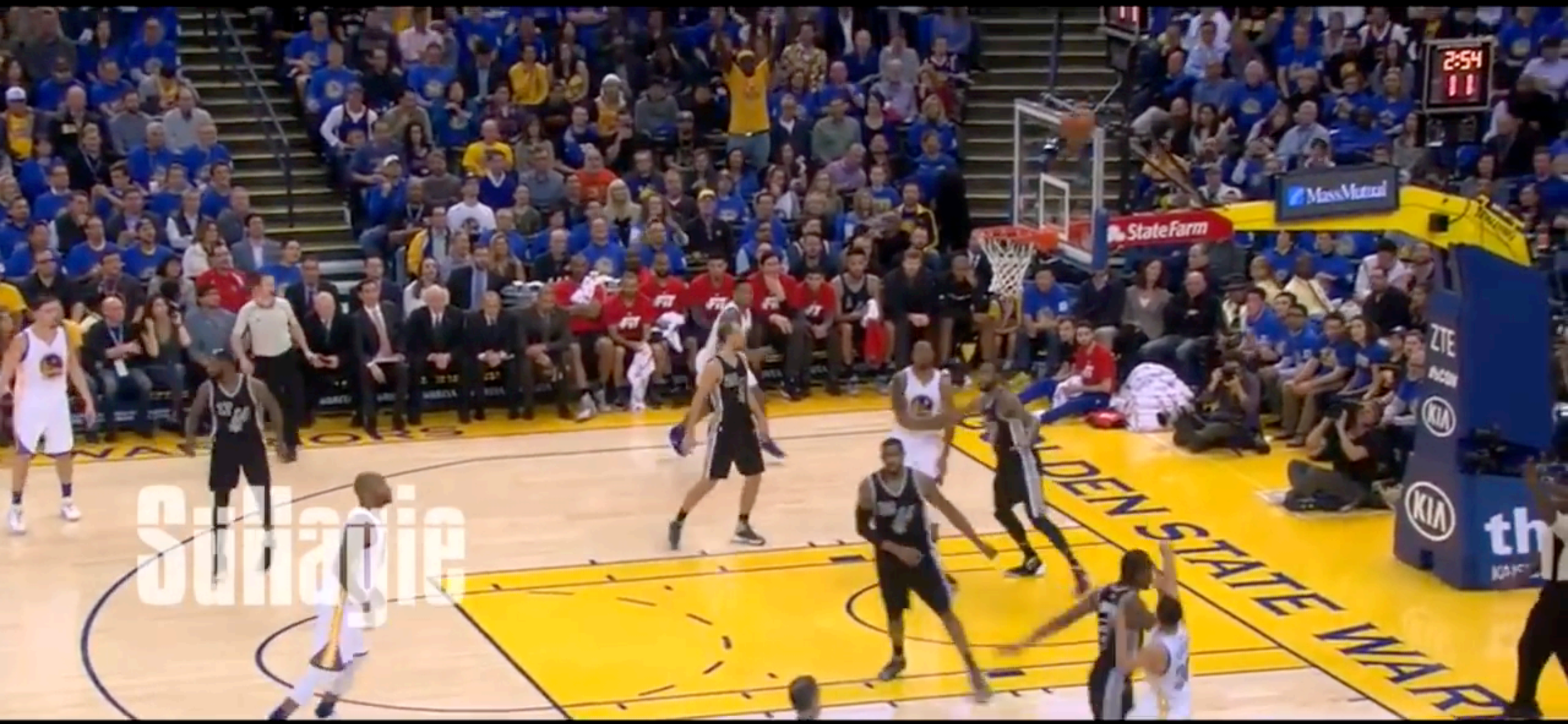
When and how is the transition from natural lineage (above) to base-to-bit interconvertibility (below) going to matter?



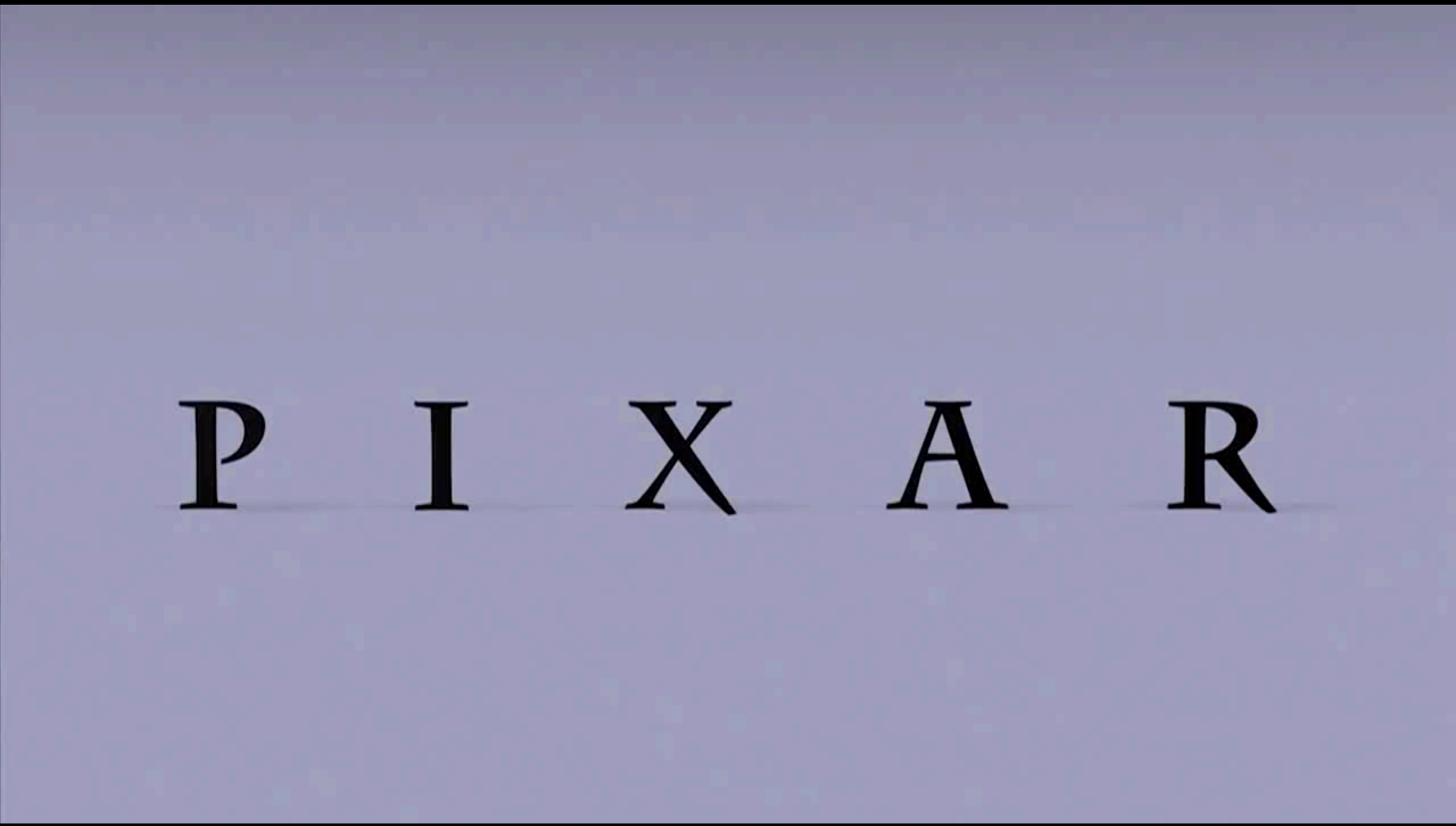
*please consider and study pre-class materials

Today's class focuses on the

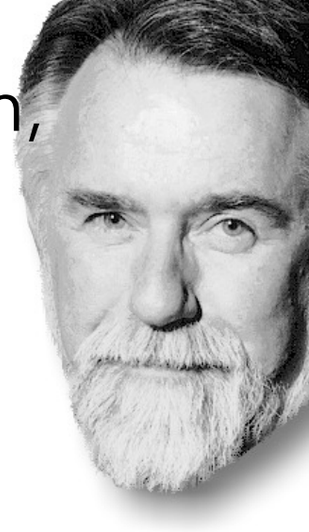
quantitative pace of change



https://youtu.be/2jwp5MEueao



Luxo Jr., Pixar Animation Studios



“When the group moved to California to become part of Lucasfilm, **we got close to making a computer-animated movie again in the mid-1980s** – this time about a monkey with godlike powers but a missing prefrontal cortex. We had a sponsor, a story treatment, and a marketing survey. We were prepared to make a screen test: Our hot young animator John Lasseter had sketched numerous studies of the hero monkey and had the sponsor salivating over a glass-dragon protagonist.

But when it came time to harden the deal and run the numbers for the contracts, **I discovered to my dismay that computers were still too slow:** The projected production cost was too high and the computation time way too long. **We had to back out of the deal.** This time, we [knew enough] to correctly apply Moore’s Law – [] **we had to wait another five years to start making the first movie**. And sure enough, **five years later Disney approached us to make Toy Story**.”

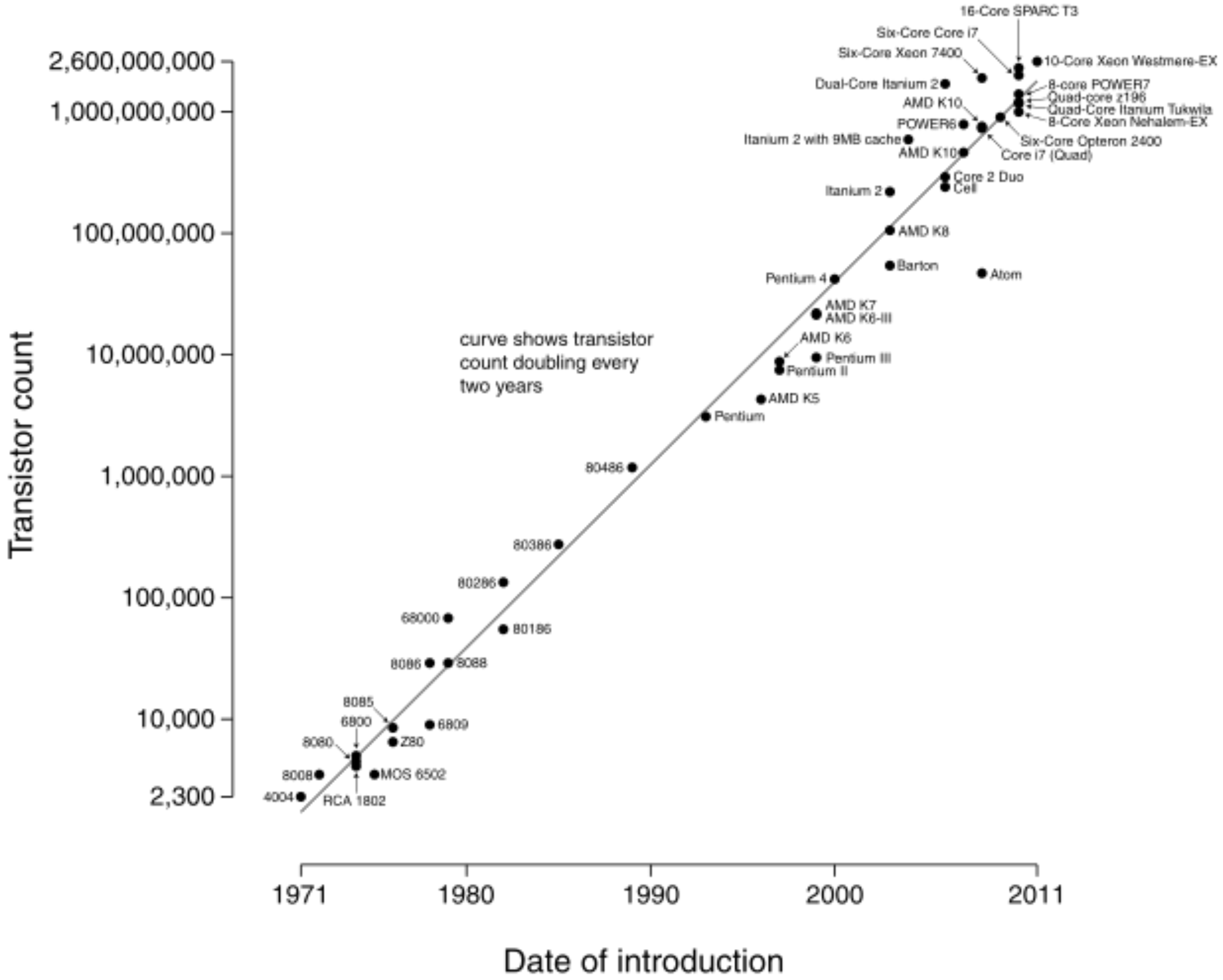
– Alvy Ray Smith

http://www.wired.com/2013/04/how-pixar-used-moores-law-to-predict-the-future/

How much cheaper did computer rendering of animated movies get between ~1985 and ~1990?

What information do you need to answer this question?

Microprocessor Transistor Counts 1971-2011 & Moore's Law



http://en.wikipedia.org/wiki/Moore%27s_law

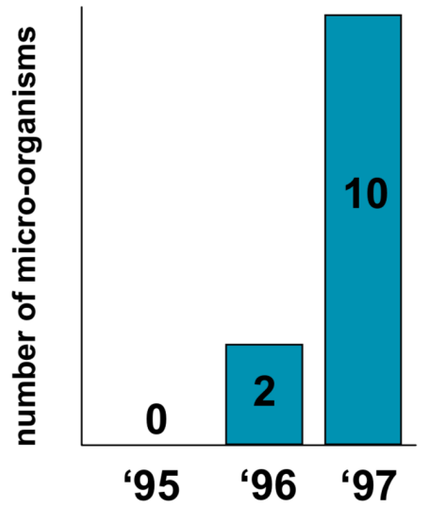
Take away lesson… for Toy Story to arrive in theaters in 1995, people had to be making smart decisions in 1985… what smart decisions should bioengineers be making today?

Cellular Computing

ISAT Summer Study, August 1996

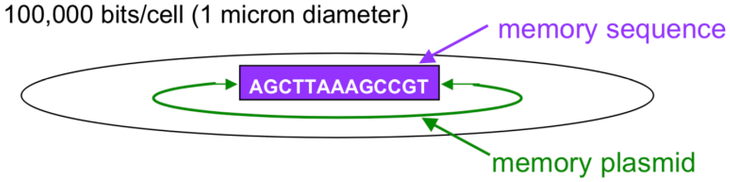
Biochemical Knowledge is Undergoing Explosive Growth

Sequenced Genomes

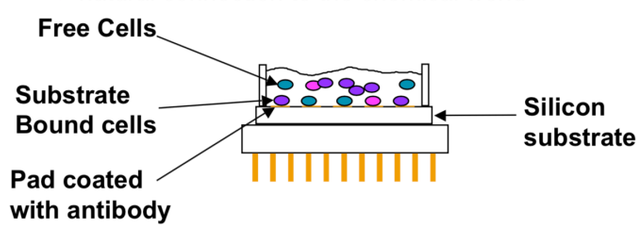


Medium Term Potential with DARPA investment

- **Dense Molecular Memory**
  - 100,000 bits/cell (1 micron diameter)

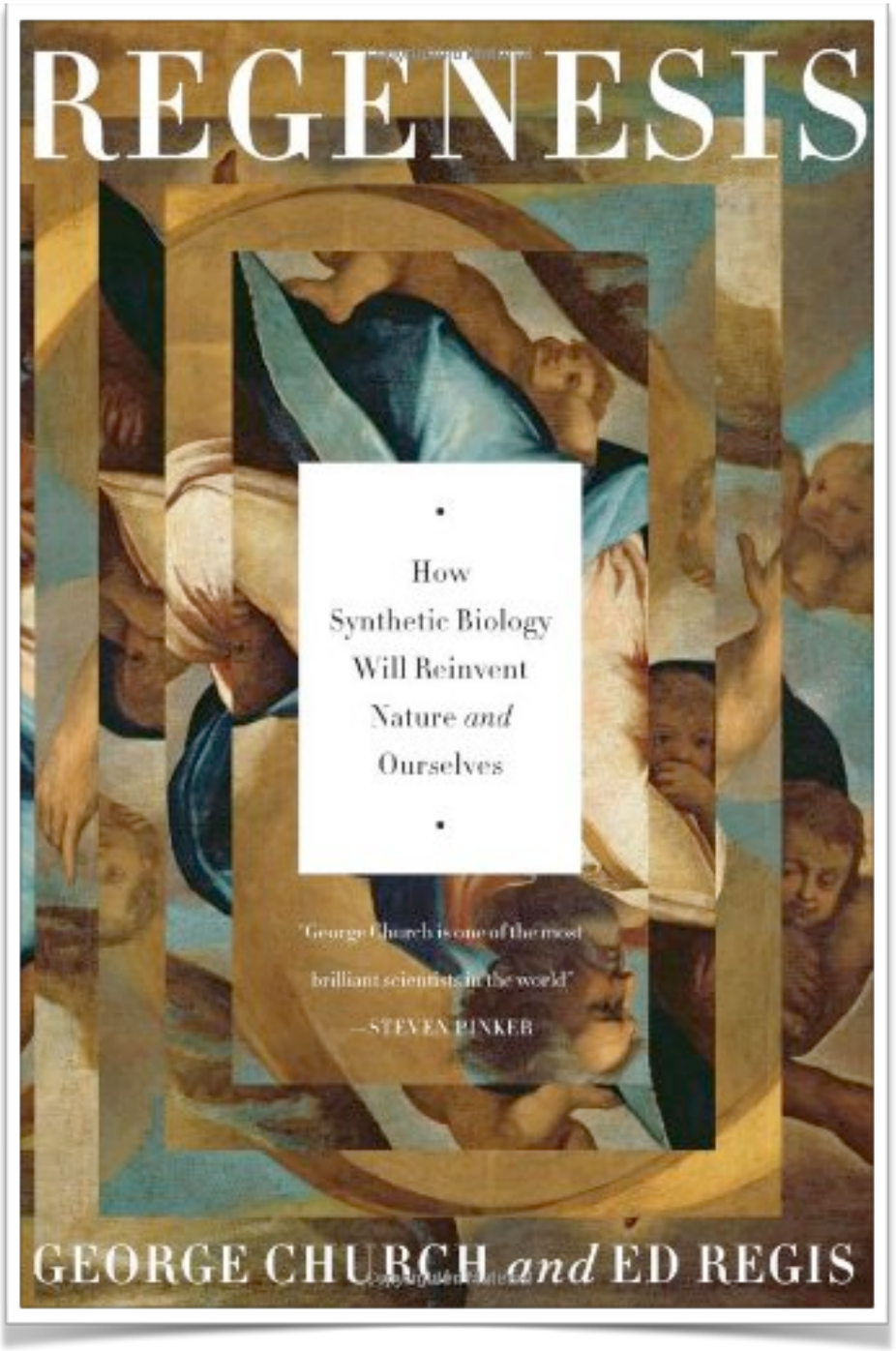


- **Hybrid Silicon / Cell Structures**
  - silicon computation
  - biological interfaces
    - natural connection to the chemical world



https://dspace.mit.edu/handle/1721.1/101009

“Surprise!” DNA is an abiotic tape for storing arbitrary digital data. Storage > biotech.



SCIENCE

The First Book To Be Encoded in DNA

Two Harvard scientists have produced 70 billion copies of a book in DNA code --and it's smaller than the size of your thumbnail.

By Kharunya Paramaguru | Aug. 20, 2012 | 5 Comments

Despite the fact there are 70 billion copies of it in existence, very few people have actually read the book *Regenesis: How Synthetic Biology Will Reinvent Nature and Ourselves in DNA*, by George Church and Ed Regis. The reason? It is written in the basic building blocks of life: Deoxyribonucleic acid, or DNA.

Church, along with his colleague Sriram Kosuri, both molecular geneticists from the Wyss Institute for Biologically Inspired Engineering at Harvard, used the book to demonstrate a breakthrough in DNA data storage. By copying the 53,000 word book (alongside 11 jpeg images and a computer program) they’ve managed to squeeze a thousand times more data than ever previously encoded into strands of DNA, as reported in the August 17 issue of the journal *Science*. (To give you some idea of how much information we’re talking about, 70 billion copies is more than three times the total number of copies for the next 200 most popular books in the world combined.)

Lisa Poole / AP FILE

In his lab at the Harvard Medical School in Boston, George Church, Harvard Medical School Genetics professor, shows DNA sequence data for Dr. John Halamka, chief information officer, following a news conference on Monday, Oct. 20, 2008 where a group of mostly scientists and researchers said they will post their medical records and DNA sequence of some of their own genes online for the sake of research. Both George Church and Dr. Halamka are part of the group that plan to post their medical and DNA sequence of some of their own genes online.

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PooPrints pioneered the science of DNA Waste Management over 10 years ago, and has been leading the industry ever since.

Cell

Rapid, Low-Cost Detection of Zika Virus Using Programmable Biomolecular Components

The recent Zika virus outbreak highlights the need for low-cost diagnostics that can be rapidly developed for distribution and use in pandemic regions. Here, we report a pipeline for the rapid design, assembly, and validation of cell-free, paper-based sensors for the detection of the Zika virus RNA genome. By linking isothermal RNA amplification to toehold switch RNA sensors, we detect clinically relevant concentrations of Zika virus sequences and demonstrate specificity against closely related Dengue virus sequences. When coupled with a novel CRISPR/Cas9-based module, our sensors can discriminate between viral strains with single-base resolution. We successfully demonstrate a simple, field-ready sample-processing workflow and detect Zika virus from the plasma of a viremic macaque. Our freeze-dried biomolecular platform resolves important practical limitations to the deployment of molecular diagnostics in the field and demonstrates how synthetic biology can be used to develop diagnostic tools for confronting global health crises.

Cell

Rapid, Low-Cost Detection of Zika Virus Using Programmable Biomolecular Components

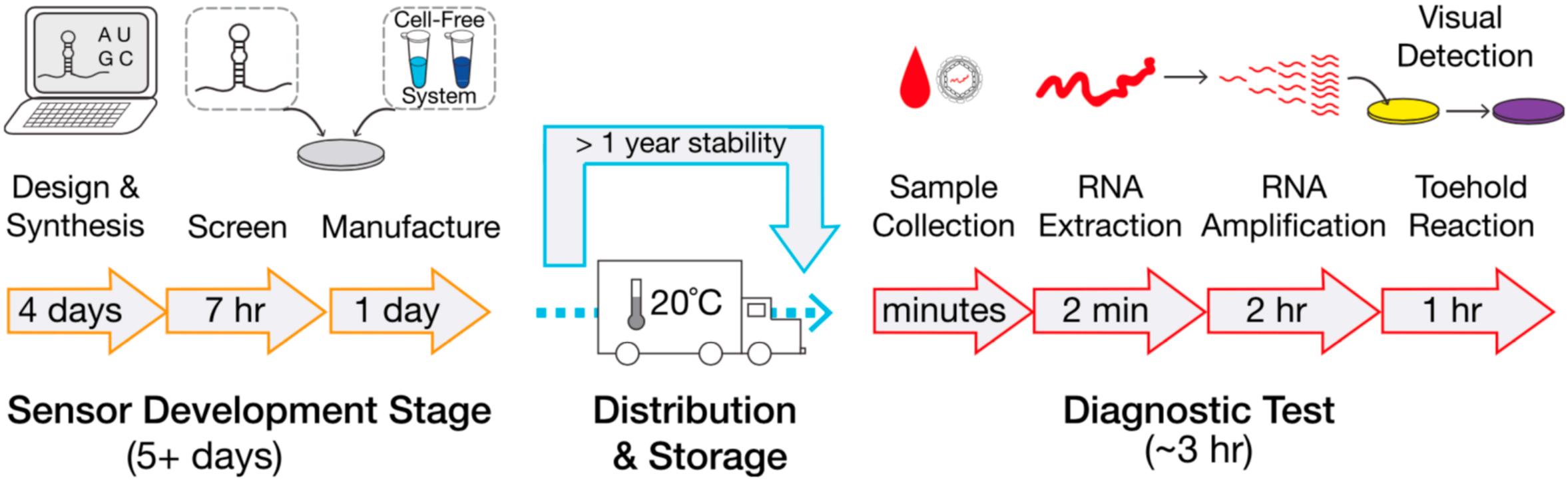


Figure 1. Workflow for the Rapid Prototyping of Paper-Based, Biomolecular Sensors for Portable and Low-Cost Diagnostics

The SemiSynBio Roadmap identifies technology targets/goals in the following five technical areas:

1. DNA-based Massive Information Storage.
2. Energy Efficient, Small Scale Cell-Based and Cell-inspired Information Systems.
3. Intelligent Sensor Systems and Cell/Semiconductor Interfaces.
4. Electronic-Biological System Design Automation.
5. Biological pathways for semiconductor fabrication and integration.

https://www.src.org/program/grc/semisynbio/

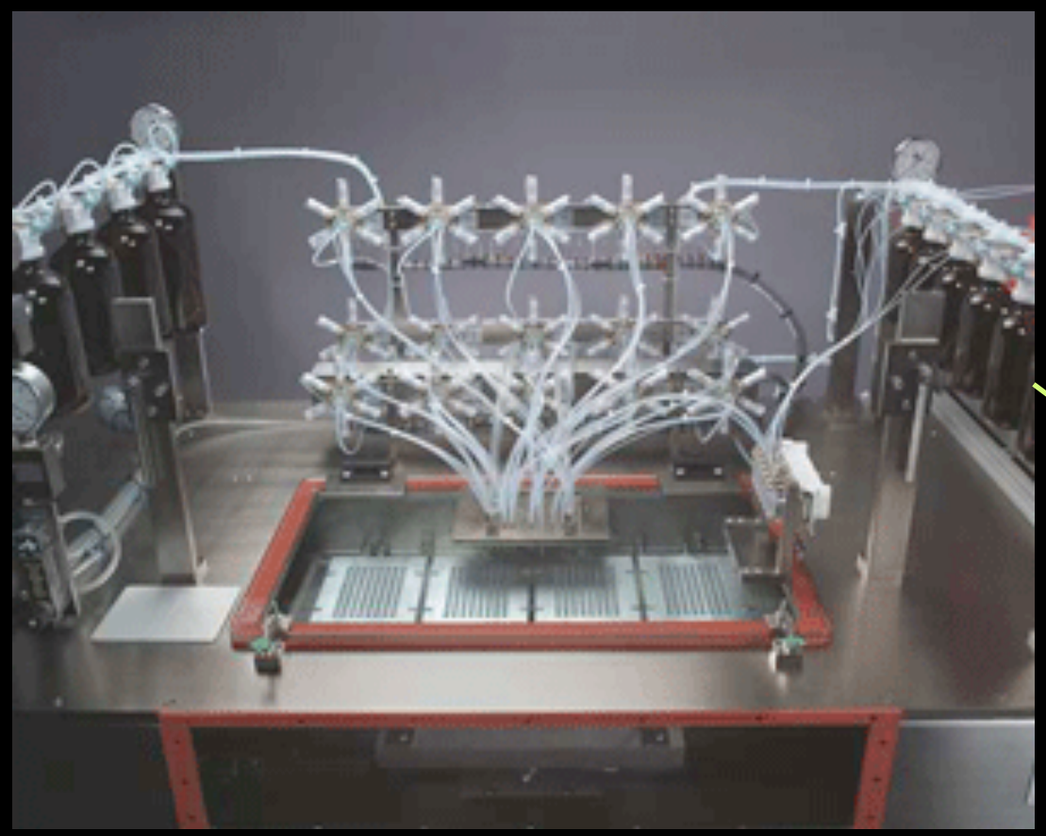
~2003

...building genes cost $4 per basepair!

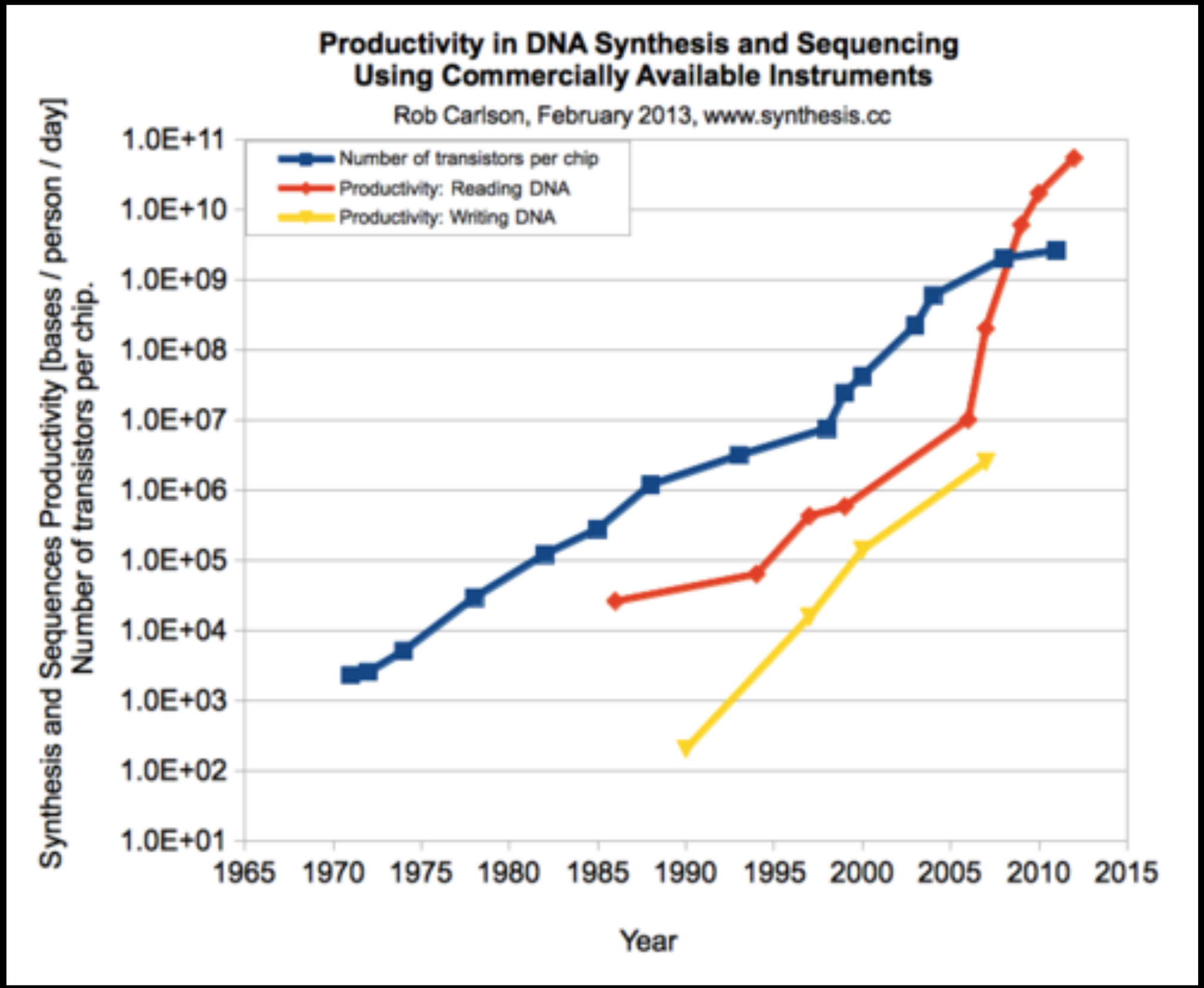
DNA synthesis = 4 key keyboard for genetic stuff

Raw chemicals, not derived from existing DNA

TAATACGACTCACTATAGGGAGA



Play however you like to get the DNA you want, from scratch.



https://synbiobeta.com/time-new-dna-synthesis-sequencing-cost-curves-rob-carlson/

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

Researchers Say They Created a 'Synthetic Cell'

By **NICHOLAS WADE** MAY 20, 2010

The genome pioneer J. Craig Venter has taken another step in his quest to create synthetic life, by synthesizing an entire bacterial genome and using it to take over a cell.

Dr. Venter calls the result a "synthetic cell" and is presenting the research as a landmark achievement that will open the way to creating useful microbes from scratch to make products like vaccines and biofuels. At a press conference Thursday, Dr. Venter described the converted cell as "the first self-replicating species we've had on the planet whose parent is a computer."

"This is a philosophical advance as much as a technical advance," he said, suggesting that the "synthetic cell" raised new questions about the nature of life.

Other scientists agree that he has achieved a technical feat in synthesizing the largest piece of DNA so far — a million units in length — and in making it accurate enough to substitute for the cell's own DNA.

https://www.nytimes.com/2010/05/21/science/21cell.html

Rep. Joe Barton of Texas said he would eagerly provide backing for development of a synthetic genome “that would predispose folks to vote Republican.”

Washington DC, US House of Representatives, 27 May 2010

8 June 2015 **BioE 80 – Final Exam** **Total Points: 100**

0. Your Name (2 points):

1. Nature+Nurture or Fab-a-Family? (20 points):

Over the past 12 years the price of synthesizing genes has dropped from $4 to $0.04 per base pair; presume the future price for DNA synthesis will continue to drop two fold every two years.

Meanwhile, Stanford's undergraduate tuition is approximately $50,000 per year up from $25,000 in 2000. Presume Stanford's tuition will continue to double every 15 years.

1a. If a human genome is 4 billion base pairs long then when will the cost of synthesizing the DNA encoding an entire human genome be roughly the same as the tuition cost associated with attending Stanford for one year? Hint: use the facts given, keep your math simple, and write it out. An approximate answer is fine.

10.1126/science.aaf6850 (2016).

The Genome Project–Write

Jef D. Boeke,*† George Church, * Andrew Hessel, * Nancy J. Kelley,* Adam Arkin, Yizhi Cai, Rob Carlson, Aravinda Chakravarti, Virginia W. Cornish, Liam Holt, Farren J. Isaacs, Todd Kuiken, Marc Lajoie, Tracy Lessor, Jeantine Lunshof, Matthew T. Maurano, Leslie A. Mitchell, Jasper Rine, Susan Rosser, Neville E. Sanjana, Pamela A. Silver, David Valle, Harris Wang, Jeffrey C. Way, Luhan Yang

*These authors contributed equally to this work.

†Corresponding author. Email: jef.boeke@nyumc.org

The list of author affiliations is available in the supplementary materials.

We need technology and an ethical framework for genome-scale engineering

The Human Genome Project ("HGP-read") nominally completed in 2004 aimed to sequence the human genome and improve technology, cost, and quality of DNA sequencing (*1*, *2*). It was biology's first genome-scale project, and at the time was considered controversial by some. Now it is recognized as one of the great feats of exploration, one that has revolutionized science and medicine.

Although sequencing, analyzing, and editing DNA continue to advance at breakneck pace, the capability to construct DNA sequences in cells is mostly limited to a small number of short segments, restricting the ability to manipulate and understand biological systems. Further understanding of genetic blueprints could come from construction of large, gigabase (Gb)–sized animal and plant genomes, including the human genome, which would in turn drive development of tools and methods to facilitate large-scale synthesis and editing of genomes. To this end, we propose the Human Genome Project–Write (HGP-write).

We will enable broad public discourse on HGP-write; having such conversations well in advance of project implementation will guide emerging capabilities in science and contribute to societal decision-making. Through open and ongoing dialogue, common goals can be identified. Informed consent must take local and regional values into account and enable true decision-making on particularly sensitive use of cells and DNA from certain sources. Finally, the highest biosafety standards should guide project work, and safety for lab workers, research participants, and ecosystems should pervade the design process. A priority will be cost reduction of both genome engineering and testing tools to aid in equitable distribution of benefits—e.g., enabling research on crop plants and infectious agents and vectors in developing nations.

To ensure responsible innovation and ongoing consideration of ELSI, a percentage of all research funds could be

https://en.wikipedia.org/wiki/Genome_Project-Write

What ***changes*** might bioengineers realize via DNA?

Given trends, when would be the right time to start organizing to ***make the changes you want?***

*reminder! consider and study pre-class materials