

Remote Biology Labs

Accessible and Ubiquitous Biology Technology

Austin Che

austin@csail.mit.edu



**Massachusetts
Institute of
Technology**

E-ducation Without Borders

Abu Dhabi, UAE

The Coming Biology Age

Introduction

- The Biology Age
- Science to Engineering
- Synthetic Biology

Proposal

Need

Impact



Stone



Bronze



Iron

The Coming Biology Age

Introduction

- The Biology Age
- Science to Engineering
- Synthetic Biology

Proposal

Need

Impact



Stone



Bronze



Iron



Silicon

The Coming Biology Age

Introduction

- The Biology Age
- Science to Engineering
- Synthetic Biology

Proposal

Need

Impact



Stone



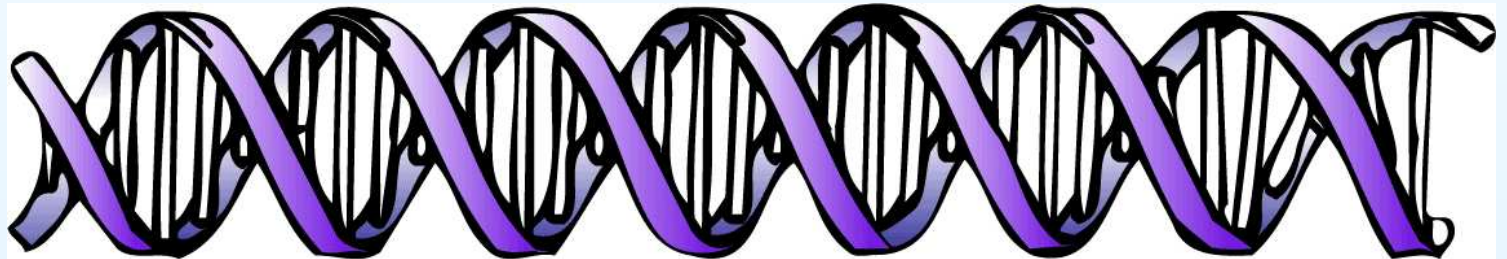
Bronze



Iron



Silicon



Carbon

The Transition from Science to Engineering

*A Scientist discovers that which exists.
An Engineer creates that which never was.*

-Theodore von Karman

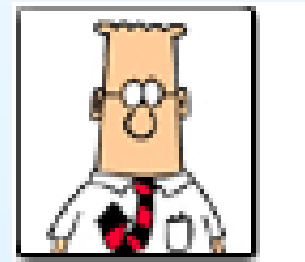
Introduction

- The Biology Age
- **Science to Engineering**
- Synthetic Biology

Proposal

Need

Impact



The Transition from Science to Engineering

*A Scientist discovers that which exists.
An Engineer creates that which never was.*

-Theodore von Karman

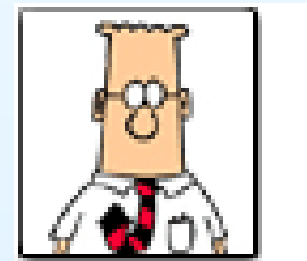
Introduction

- The Biology Age
- **Science to Engineering**
- Synthetic Biology

Proposal

Need

Impact



The Grand Canyon

The Emergence of Synthetic Biology

Introduction

- The Biology Age
- Science to Engineering
- Synthetic Biology

Proposal

Need

Impact

Accessible Technology and Ubiquitous Products

Engineering

Science

The Emergence of Synthetic Biology

Computers and consumer electronics

Electrical Engineering

Physics

Introduction

- The Biology Age
- Science to Engineering
- Synthetic Biology

Proposal

Need

Impact

The Emergence of Synthetic Biology

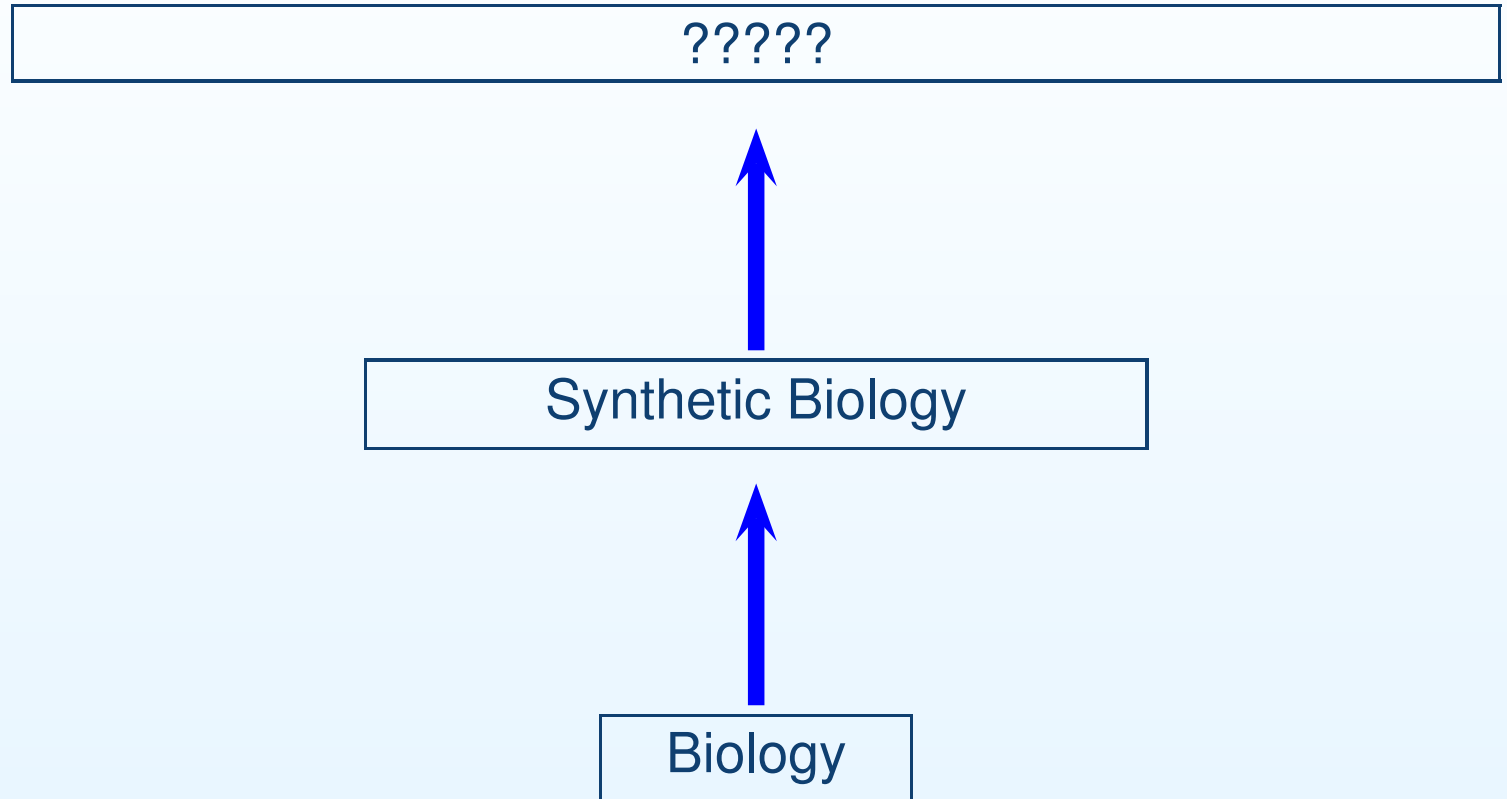
Introduction

- The Biology Age
- Science to Engineering
- Synthetic Biology

Proposal

Need

Impact



<http://www.syntheticbiology.org/>

Synthetic Biology: Design and build new biological parts, devices and integrated biological systems

Remotely Controlled Biology Labs

Introduction

Proposal

- Remote Labs
- Biohackers
- Classroom
- Research
- Variable Control

Need

Impact



Internet



Remotely Controlled Biology Labs

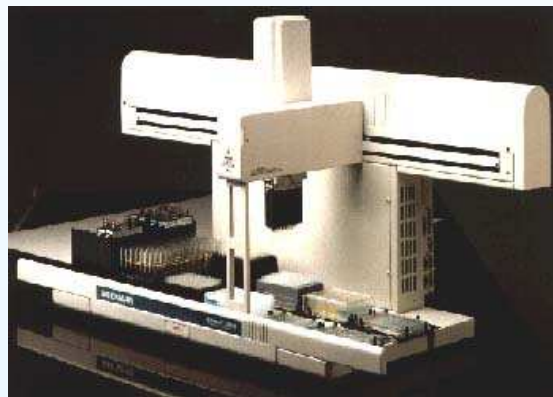
Introduction

Proposal

- Remote Labs
- Biohackers
- Classroom
- Research
- Variable Control

Need

Impact



Internet



Remotely Controlled Biology Labs

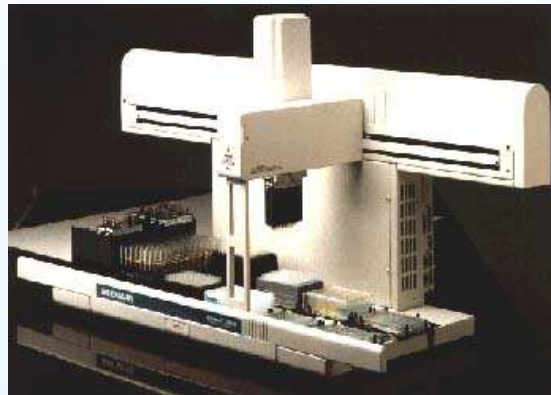
Introduction

Proposal

- Remote Labs
- Biohackers
- Classroom
- Research
- Variable Control

Need

Impact



Internet



Remotely Controlled Biology Labs

Introduction

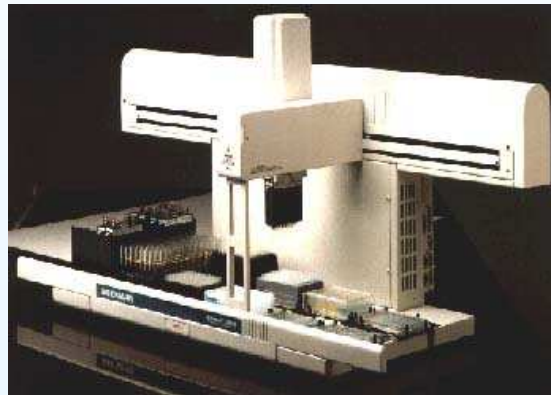
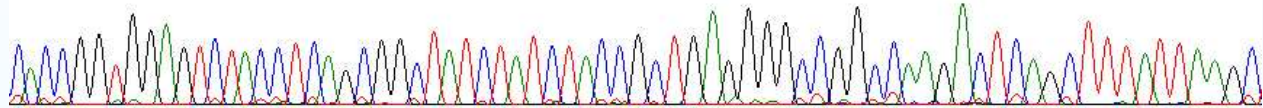
Proposal

- Remote Labs
- Biohackers
- Classroom
- Research
- Variable Control

Need

Impact

CACCGGTGGAGTCTACCTCAGCGGGCTATCTATCTACCGCTGAGGGCCGGCCAAGACTCAGCTTTATTAAGC
80 90 100 110 120 130 140



Internet



Remotely Controlled Biology Labs

Introduction

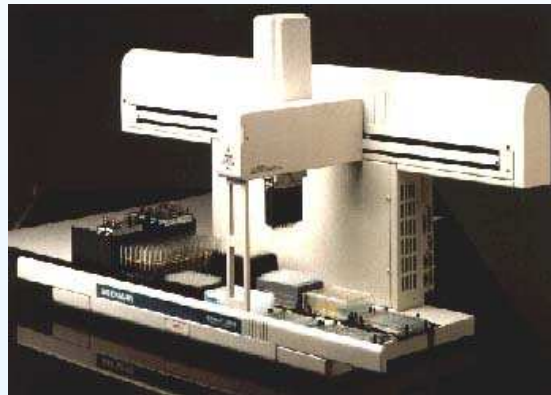
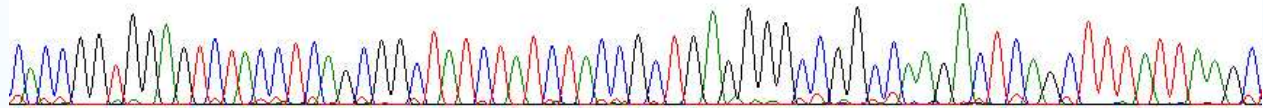
Proposal

- Remote Labs
- Biohackers
- Classroom
- Research
- Variable Control

Need

Impact

CACCGGTGGAGTCTACCTCAGCGGGCTATCTATCTACCGCTGAGGGCCGGCCAAGACTCAGCTTTATTAAGC
80 90 100 110 120 130 140



Internet



Remotely Controlled Biology Labs

Introduction

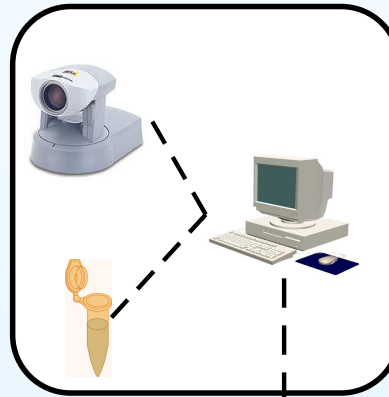
Proposal

- Remote Labs
- Biohackers
- Classroom
- Research
- Variable Control

Need

Impact

Self Contained Lab



Internet



Training the Next Generation Biohackers

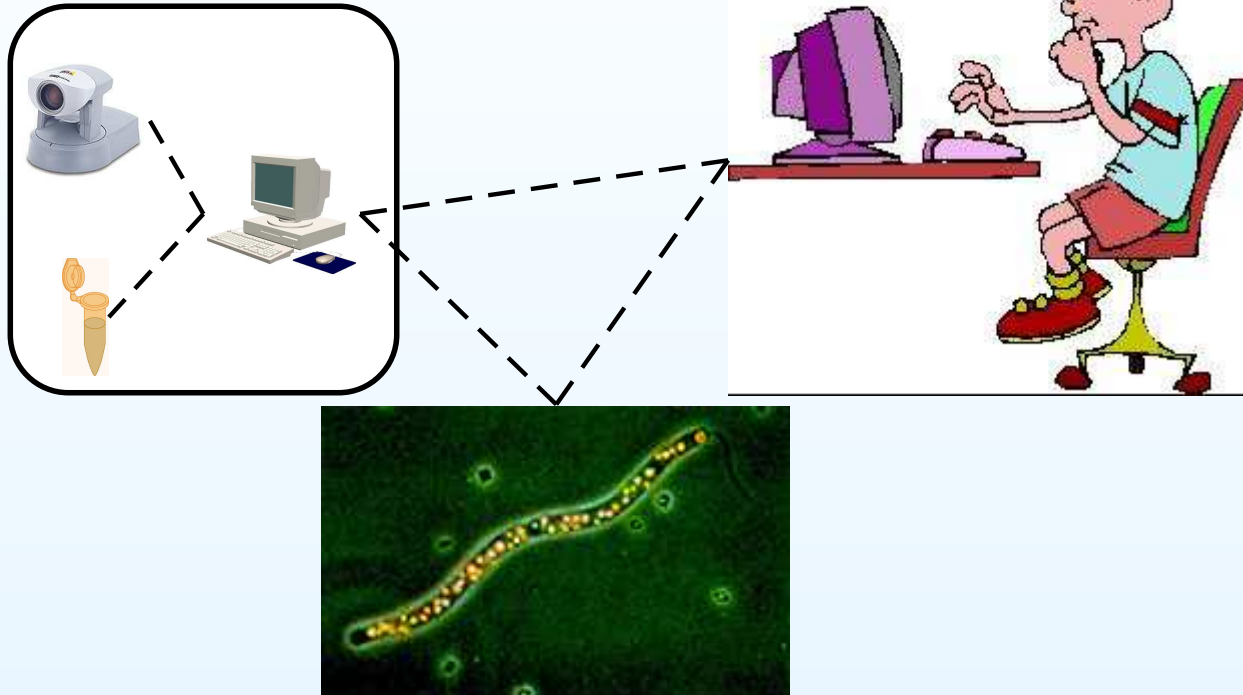
Introduction

Proposal

- Remote Labs
- **Biohackers**
- Classroom
- Research
- Variable Control

Need

Impact



- Safe, inexpensive, and fun environment to learn
- Begin experimenting while young
- Many details are hidden

Classroom Lab Education

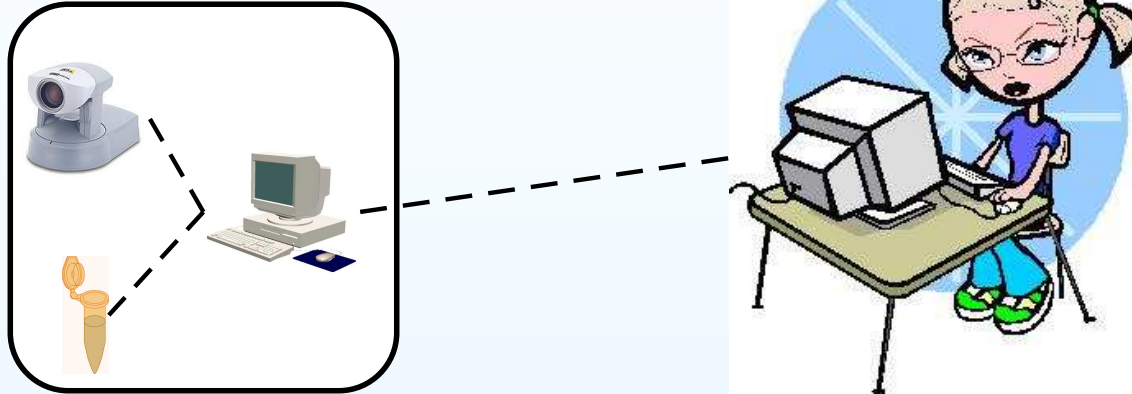
Introduction

Proposal

- Remote Labs
- Biohackers
- **Classroom**
- Research
- Variable Control

Need

Impact



- Teacher specifies permissible operations
- Saves time and cost of lab supervision
- Focus on specific educational goals

Research Education

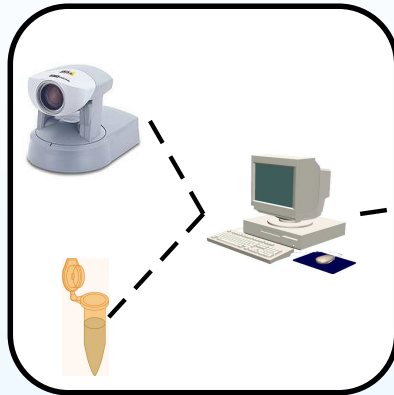
Introduction

Proposal

- Remote Labs
- Biohackers
- Classroom
- **Research**
- Variable Control

Need

Impact



- Saves muscles from pipetting overdose
- Reduces time to learn and relearn lab protocols
- High degree of control (if desired)

Variable Human Control

Introduction

Proposal

- Remote Labs
- Biohackers
- Classroom
- Research
- Variable Control

Need

Impact



Variable Human Control

Introduction

Proposal

- Remote Labs
- Biohackers
- Classroom
- Research
- Variable Control

Need

Impact



Creative insight
Hypothesis generation
Result analysis

Experiment design

Protocol selection

Equipment operation

Pipetting

Prepare materials

Lab maintenance

Waiting

Variable Human Control

Introduction

Proposal

- Remote Labs
- Biohackers
- Classroom
- Research
- Variable Control

Need

Impact



Creative insight
Hypothesis generation
Result analysis

Experiment design

Protocol selection

Equipment operation

Pipetting

Prepare materials

Lab maintenance

Waiting



Variable Human Control

Introduction

Proposal

- Remote Labs
- Biohackers
- Classroom
- Research
- Variable Control

Need

Impact



Creative insight
Hypothesis generation
Result analysis

Experiment design

Protocol selection

Equipment operation

Pipetting

Prepare materials

Lab maintenance

Waiting

Variable Human Control

Introduction

Proposal

- Remote Labs
- Biohackers
- Classroom
- Research
- Variable Control

Need

Impact



Creative insight
Hypothesis generation
Result analysis

Experiment design

Protocol selection

Equipment operation
Pipetting
Prepare materials
Lab maintenance
Waiting

Variable Human Control

Introduction

Proposal

- Remote Labs
- Biohackers
- Classroom
- Research
- Variable Control

Need

Impact



Robot Scientist

King, Ross D., et al. "Functional genomic hypothesis generation and experimentation by a robot scientist." *Nature* 427 (Jan. 2004): 247–252. [doi:10.1038/nature02236](https://doi.org/10.1038/nature02236)



Creative insight
Hypothesis generation
Result analysis

Experiment design

Protocol selection

Equipment operation

Pipetting

Prepare materials

Lab maintenance

Waiting

Work Efficiency

*If necessity is the mother of invention,
laziness is the father of invention.*

Efficiency: The ratio of useful work to energy expended.
(Webster's)

Introduction

Proposal

Need

- Work Efficiency
- Work Planning
- Motivation Timing

Impact

Work Efficiency

*If necessity is the mother of invention,
laziness is the father of invention.*

Introduction

Proposal

Need

- Work Efficiency
- Work Planning
- Motivation Timing

Impact

~~Efficiency: The ratio of useful work to energy expended.
(Webster's)~~

Efficiency: Being able to do useful work in the rare times I
have energy and want to work. (Austin's)

Efficiency:



Work Efficiency

*If necessity is the mother of invention,
laziness is the father of invention.*

Introduction

Proposal

Need

- Work Efficiency
- Work Planning
- Motivation Timing

Impact

~~Efficiency: The ratio of useful work to energy expended.
(Webster's)~~

Efficiency: Being able to do useful work in the rare times I
have energy and want to work. (Austin's)

Efficiency:



Work Efficiency

*If necessity is the mother of invention,
laziness is the father of invention.*

Introduction

Proposal

Need

- Work Efficiency
- Work Planning
- Motivation Timing

Impact

~~Efficiency: The ratio of useful work to energy expended.
(Webster's)~~

Efficiency: Being able to do useful work in the rare times I
have energy and want to work. (Austin's)

Efficiency:



Work Efficiency

*If necessity is the mother of invention,
laziness is the father of invention.*

Introduction

Proposal

Need

- Work Efficiency
- Work Planning
- Motivation Timing

Impact

~~Efficiency: The ratio of useful work to energy expended.
(Webster's)~~

Efficiency: Being able to do useful work in the rare times I
have energy and want to work. (Austin's)

Efficiency:



Work Efficiency

*If necessity is the mother of invention,
laziness is the father of invention.*

Introduction

Proposal

Need

- Work Efficiency
- Work Planning
- Motivation Timing

Impact

~~Efficiency: The ratio of useful work to energy expended.
(Webster's)~~

Efficiency: Being able to do useful work in the rare times I
have energy and want to work. (Austin's)

Efficiency:



Work Efficiency

*If necessity is the mother of invention,
laziness is the father of invention.*

Introduction

Proposal

Need

- Work Efficiency
- Work Planning
- Motivation Timing

Impact

~~Efficiency: The ratio of useful work to energy expended.
(Webster's)~~

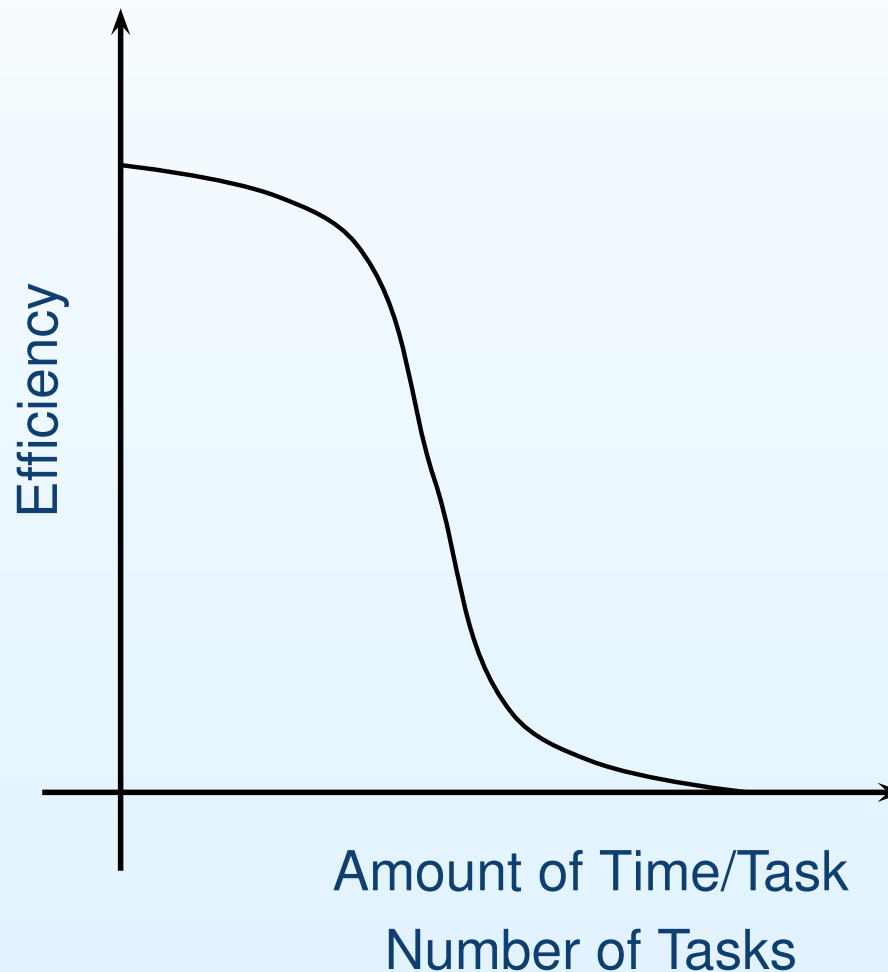
Efficiency: Being able to do useful work in the rare times I
have energy and want to work. (Austin's)

Efficiency:



Work Time Fragmentation and Planning

⇒ *Work efficiency is inversely related to the average amount of time it takes to perform individual tasks and to the number of individual tasks.*



Introduction

Proposal

Need

- Work Efficiency
- **Work Planning**
- Motivation Timing

Impact

Work Time Timing

⇒ *Work motivation fluctuates and efficiency will be greatest when work can be done at the same time one has high motivation.*

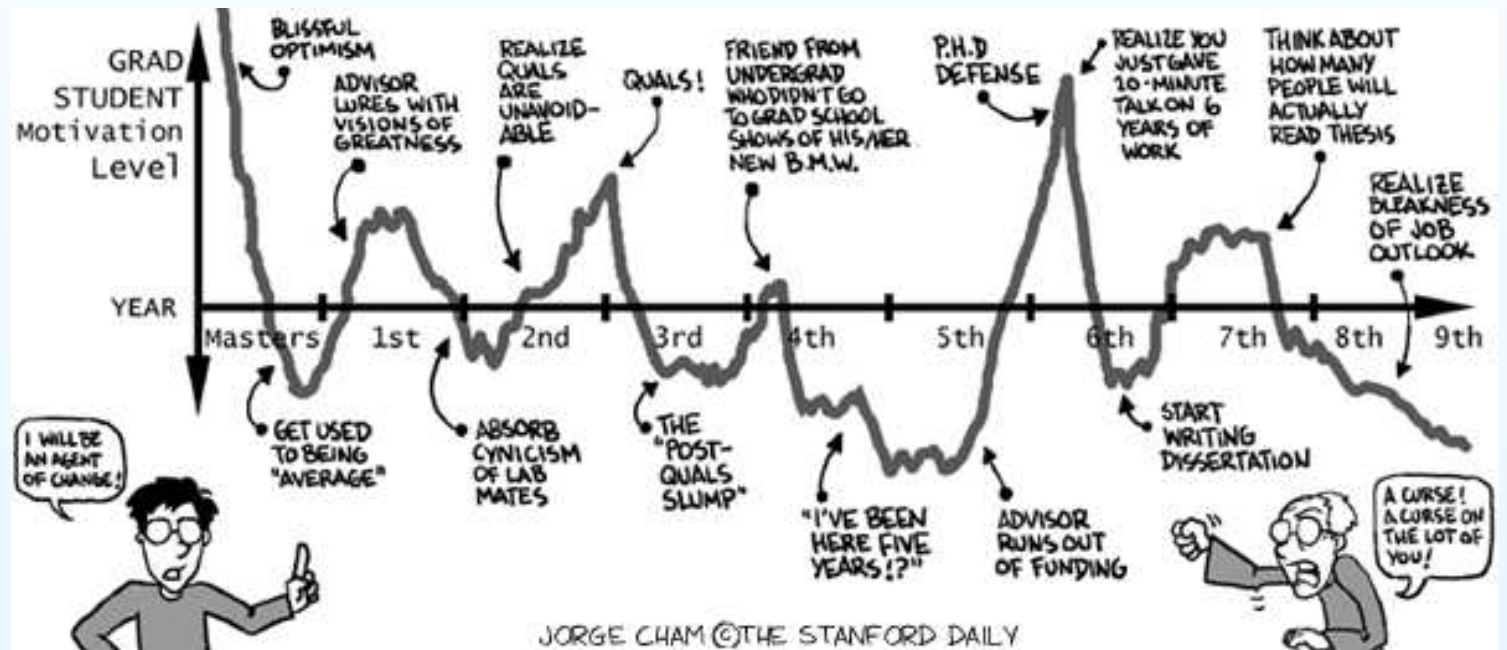
Introduction

Proposal

Need

- Work Efficiency
- Work Planning
- Motivation Timing

Impact



(Piled Higher and Deeper)

Ethics: Are we ready?

There is no great invention, from fire to flying, which has not been hailed as an insult to some god.

-J.B.S. Haldane, Daedalus, or Science and the Future (1923)



Alba, The GFP Bunny (Eduardo Kac)

Introduction

Proposal

Need

Impact

- Ethics
- Risk
- Conclusion

Risk and Safety

Introduction

Proposal

Need

Impact

- Ethics
- Risk
- Conclusion

TTAAACAGCTCTGGGGTGTACCCACCCAGAGGCCACGTGGCGGCTAGTACTCCGGTATGCGGTACCCTTGTACGCCTGTTTTACTCCCTTCCCGTAACTTAGACGCACAAAACAAGT
TCAATAGAAGGGGTACAAACAGTACCACCCAGCAACAGCACTTCTGTTTTCCCGGTGATGTCTTACTAGACTGCTTGGCGTGTGAAAGCGACGGATCCGTTATCCGCTTATGTACTTCGAGAA
CCCCAGTACCACCTCGGAATCTTCGATGCGTGGCTCAGCCTAACCCCAAGGTAGTCTTAGGCTAGTAGTCTGGACATCCCTCAGCGTACCGGTGACCGTGGTGGCGGCTAC
CTATGGCTAACGCCATGGGACGCTAGTTGTGAACAAGTGTGAAGAGCCTATTGAGTACATAAGAATCTCCGGCCCTGAATCGGCTAATCCCACTCGGAGCAGGTGGTCACAAACAGT
GATTGGCCTGTCGTAACCGCGAAGTCCGTTGGCGGAACCGACTACTTTGGGTGTCGCTGTTTCTTTATTTTATTGTTGGCTGCTTATGGTGACAATCACAGATGTTATCATAAAGCGAATGGGA
TTGGCCATCCGGTGAAAGTGAAGTACTATTATCTATCTGTTTGGCTGGATCCGCTCCATTGAGTGTGTTTTACTCTAAGTACAATTTCAACAGTATTTCAATCAGACAATGTATCATAAATGGGTG
TCAGGTTTCATCAGAAAAGTGGGCGCACATGAAAACCTCAATAGAGCCTATGGTGGTCTACCATTAAATACACCACCATTAAATATATAGAGATTCAGCTAGTAAACGGGCTTCGAAACAGG
ACTTCTCTCAAGACCTTCCAAGTTCACCGAGCCATCAAGGATGTCCTGATAAAAAACAGCCCAATGCTAACTCGCCAAACATAGAGGCTTGGGGTATAGCGATAGACTGCAATTAACA
CTGGAAACTCCACTATAACACACAGGAGGCGGCTAATTCAGTAGTCCGTTATGGCGCTTGGCCTGAATATCTGAGGACAGCGGAAGCCAACTCCAGTGGACCCAGCCAGACAAACAGCCTCGC
TGCAATGCAAGTTTTTATACGCTAGACACCGTGTCTTGGACGAAAGAGTCCGCGAGGTTGGTGGAAAGTTCGCTGATGCATGAGGACATGGGACTTTGGGCAAAAATGTACTACCCTACC
TAGGTAGTCCGGGTACCCGTGATGTACAGTGAACGCCCTCCAATTCACAGGGGGCACTAGGGGTATTCCCGTACCAGAGATGTGCTGGCCGGGATAGCAACACCACCTACCATTGCAC
ACCAGCTATCAAAATGCCAATCTGGCGAGAAAGGAGGCATTTACGGGTACGTTCACTCTGCACAAACACAGACATCACCTGCCCGAGGTTCTGGCCGGTGGATTACCTCTTGGAAATGG
CACGTTGTTGGGGAATGCCTTTGTGTTCCCGCACAGATAAAACCTACGGACCAACAACCTGTGCTACACTGGTACTCCCTTACGTGAACCTCCCTCGATAGATAGTATGGTAAAGCACAATA
ATTGGGGAATTGCAATATTACCATTGGCCCAATTAATTTTGTAGTGTGCTCCCGCAGAGATCCAACTCACCTTGACCATAGCCCTATGTGCTGTGAGTTCAATGGATTAAGAAAACATCACC
CTGCCACGCTTACAGGGCTGCGGTCATGAACACCCCTGGTAGCAATCAATATCTTACTGCAGACAACCTCCAGTACCGGTGTGGCTGCCTGAATTTGATGTGACCCCACTTATGACATAC
CGGTGAAGTAAAGAATAGTGAATTTGGCAGAAATCGACACCATGATTCCTTTGACTTAAAGTCCCAAAAAGAACACCACTGGAAATGTATAGGTTCCGTTAAGTGACAAAACACACATACAG
ACGATCCCATCTGCTGTCACTCTCCAGCTCAGATCCTAGGTTGTACATACACTGCTTGGAGAAAATCTAAATTAATAACACACTGGGCAGGATCCCTGAAGTTACGTTCTGTTCT
TGTGGATTTCATGATGGCAACTGGCAACTGTTGGTGTCTATCGCGCTCTGGAGCCGACCCACCAAGAGGTAAGGAGGCGATGTTGGGAACACATGTGATCTGGGACATAGGACTGCAGTCT
CTCATGTACTATGGTAGTCCATGGATTAGCAACACCAGTATCGGCAACATAGATGATGTTCCAGGAGGGGATACATCAGGCTCTTCAACAACTAGATAGTCTGCTTTCGA
CACCCAGAGAGATGGACATCCTTGGTTTTGTGTCAGCGTGTAAATGTTTACAGGTTCCAGGTCGGCTGTTGCGAGATACACACATATAGAGCAAAAAGCCGTAGCACAGGGGTTAGTGCAGTGTGAA
AGCATGATTGACAACACAGTCCGTAACCGGTGGGGCGGCAACATCTAGAGAGCCTCTCCCAACACTGAAGCCAGTGGACCAACACACTCCAAGGAAATTCGGGCACTCCCGGAGTGGAAAC
TGGGCCCACAAATCCACTAGTCCCTTCTGATACAGTGAACACCCAGACATGTTGTACAACATAGGTTCAAGGTGAGTCTAGCATAGAGTCTTCTTCGCGCGGGGTGATGGGTGACCATATGA
CCGTGGATAACCCAGCTTCCACCAGAAATAGGATAAGCTATTTGCAGTGTGGAAGATCACTTATAAAGATACTGTCCAGTTACGGAGGAAATGGAGTCTTCCACTATTCTAGATTTGATATG
GAATTTACCTTTGTGGTTACTGCAAAATTTCACTGAGACTACAACATGGGATGCTTAAATCAAGTGTACCAAAATATGTAGCTACCCAGGCGCTCCAGTGGCCGAGAAATGGGACGACTACAC
ATGGCAACCTCATCAAAATCCATCAATCTTTTACACCTACGGAAACAGCTCCAGCCCGGATCTCGGTAGCTGTTGGTATTTGCAAGCCTTATTCAGACCTTTTCCAAAGTAC
CACTGAAGGACAGTGGCAGCACTAGGTACTCCCTTATGGTGCAGCATCTCAATGACTTCGGTATTTTGGCTGTTAGAGTAGTCAATGATCAACACCCGACCAAGGTACCTCCAAAATC
AGAGTGTATCTAAAACCAACACATCAGAGTCTGGTGGCCGCTCCCGAGGGCAGTGGCGTCACTCCGCGCTGGAGTGGATTAAGGATGTTACAGGATGTTACAGCTTCCACCCCTCCCAACAGGATCT
GACCAATATGGATTTCGGACACCAAAAACAAAGCGGTGACACTCGAGTTTACAAAATTTGCAACTACCCTTGGCCACTGGATGAGTATGATTGCAAAAACCGAGTGAACCTCATGTGGATGAGACCC
TCTTAGTACAGAAATCAAGAGCCAGGCGACCGATTCATCGCAAGGTGCAATTTGCAACCGAGGGGTGACTACTCGGAGTCTAGAAGGAAATACTACCAGTATCTCTGTTGGCCCAACGTTT
CAGTACATGGAGGCTAACTAATATTACCCAGTACGATCCATGCTCAATTTGGCCATGCTGCTTCCAGGAGGATGTTGGTGGCATACTCAGATGATGTTGGTGGCAGTCCACCCGGGTGATAGGAT
CATTACTGCTGGTGGCGAAGGTTGGTTGCATTTTTCAGACATTAGAGACTTGTATGCTACGAGAAAGGCCATGGAAACAGGCATACCAATTACATAGAGTCACTTGGGGCCGCAATTTGGAA
GTGGATTTACTCAGCAGATTAGCGCAAAAATACAGAGTGTACCAATATGGTGACCCAGTACCATCACTGAAAGACTACTTAAAGACTGATCAAGATCATATCTCACTAGTATTATAACTAGG
AACTATGAAGACACCCACACAGTGTCTGCTACCCCTGGCCCTTTCTGGGTGTGATGCTTCAACATGGCAGTGGCTTAGAAAGAACAGCATGCGATGTTCTGGAGATACCTTATGTCAAGCAAGG
TGACAGTGGTTGAAGAAGTTTACTGAAGCATGAACCGAGCTAAGGGACTGGAGTGGGTGCAAAACAAATCTCAAATTCATTGATTGGCTCAAGGAGAAATATCCCAAGGTAGAGATA
AGTTGGAATTTGTAAACAAACTTAGACAACATGAAATGCTGGAAAACCAAACTCAACTATACCAAACTCATGCCCTAGTACAGGAAACCCAGGAAATCTTATCAATAATGTAGATGTTATCC
ATCCAGTCTAAGAGGTTTGGCCCTCTTACGCAAGTGAAGGCCAAAAGAAATACAGAAACTAGAGCATACTATTAACAACATACATACAGTTCAGAGCAAAAACCCGATTTGAAACAGTATGTTTGGT
AGTACATGGCAGCCCGGAACAGGTAATCTGTAGCAACCACTGATTGCTAGAGCCTAGCTGAAAGAGAAACACGTTCCAGTACTCGCTACCCCGGATCCATCACATCTGACGGATAC
AAACACAGGGAGTGGTGAATTTAGGACGACCTGAATCAAACCCAGATGGTGGGACATGAAGCTGTTCTGTGAGATGTTCAACAGTGGAGTTTATACCCCACTGGCATCCCTGGAGGAGAAA
GGAATCCTGTTTACTTCAAATACGTTCTAGCATCCACAAACTCAAGCAGAAATTTCCCCCCCACTGGGCAACAGTGTGATGATTAGCCAGGCGCTTTGGCGTTGCAATGGACATTCAGGTCAT
GAATGAGTATCTAGAGATGGGAAATTTGAACATGGCCATGGCTACTGAAATGTGAAGAACTGTCAACCAACAGCAAACTTAAAGAGATGCTGCTTTAGTGTGGTGAAGGCAATCAATTTAA
TGGCAAAATCTCCAGAGTTAGATACAGTATTGACAGATCACTACAATGATTTATCAATGAGAGAAACAGAAACTCAACATTTGGCAATTTGATGGAGGCTTTGTTTCAAGGACCCCTCCAGTAT
AAAGACTTGAATAATGACATCAAGCAGGTTCCCTCTGAAATGTATCAATGACTTGTCTCAAGCAGTGTACTCCAGGAGGTGAGAGATTACTGTGAGAAGAAGGTTGGATAGTCAACATCAC
CAGCCAGGTTCAAACAGAAAGGAACATCAACAGGGCAATGCAAAATCTACAAGCGGTGACAACTTCCGCGCAGTGGCTGGAGTGTCTATGTGATGATAAACTGTTTGGTGGACACAGGAG
CATACACTGGTTTACCAACACAAAACCAACAGTGGCCACCATTCGGACAGGTTGACAAAGCAGGTTGATTTACCGAGTGGCTATGGCTAAAAGAAACAAATTTGTTACAGAACTACTAGC
AAGGGAGAGTTCACTATGTTAGGAGTCCAGCACAACGTGGCTATTTTACCAACCCAGCTTCACTTGGTGAAGCATTGTGATCGATGGCAAGAAGTGGAGATCTGGATGCAAAAGCGCTCGA
AGATCAAGCAGGAACCAATCTGAAATCACTATAATCACTCTAAAAGAGAAATGAAAAGTTGAGAGACATAGACCACATATACCTACTCAAATCACTGAGACAATGATGGAGTCTTGTGCTGA
ACACTAGCAAGTACCCCAATATGATGTTTCTGCGGTGCTGTGACTGAACAGGATATCTAAATCTCCGTTGGGCGCAAACTGCTCGTACTCTAATGTACAACATTTCAACCCAGAGCAGACAG
TGTGGTGGAGTTCATACATGACTGGGAAAGTCACTGGGATGCATGTGGTGGGAACGGTTTCCACAGGGTTTGCAGCGCCCTGAAGCGATCATACTCACTCAGAGATCAAGGTGAAATCCAGT
GATGAGACCTTCAAGGAAAGTGGGATATCAATATAAATCCCGCTCAAACCAAGTTGAACCCAGTCTTCCACTATGTGTTGAAGGGTGAAGAACAGCAGCTCTCACTAAAACG
ATCCAGGCTTAAAGACAGACTTTGAGGAGGCAATTTCTCCAAAGTACGTTGGGTAACAAAATTTACTGAAAGTGGATGAGTACATGAAAGAGGCGAGTACACCACTTCTGCGCCAGTCAATGCTCACTA
GACATCAACACAGAAACAAATGTGCTTGGAGGATGCCATGTATGGCAGTATGGTCTAGAAAGCACTGATTTGCTCCAGCAGTGTGGTACCCTTATGTAGCAATGGGAAAGAAAGAGAGACAT
CTTGAACAAACAAACAGAGACACTAAGGAAATGCAAAAACCTGCTGCACAACTATGAAATCAACCTCCCACTGGTACTTGTAAAGGATGAACTTAGATCTCAAAGGATGAACTTGGTGGTGGGGA
AATCCAGATTAATGAGCTTCTAGTTTGAATGACTCAGTGGCAATGAGAAATGGCTTTGGGAACTATATGCTGCTTTTCAAAAACCCAGGAGTGAACAGGTTTCCAGCTGGGTTGGGAT
CCAGATTTGTTTGGAGCAAAATTCGGGTATGATGGAAGAGAAAGCTGTTTGTCTTTGACTACACAGGATGATGATCTCTAGCCCTGCTTGGTTCGAGGCAATAAAGATGGTCTTGGAA
AATCGGATTCGGAGACAGAGTTGACTACATCGACTACCTAAACCTCACACACCTGTACAAGGATTAACAACTACTGTTGTAAGGCGGATGACCATCTGAGGCTGCTCAGGCACTCAATTTTA
ACTCAATGATTAACAACCTGATATCAGGACACTTACTGAAAACCTACAAGGGCATAGATTTAGACCACCTAAAATGATGCTATGGTGTGATGATGATTTCTTCCATCCCACTCAAGGTT
GACGCTAGTCTCTAGCCCAATCAGGAAAAGACTATGGACTAACTAGCTCCAGCTGACAAATCAGTACATTTGAAACAGTCACTGGGAGAAATGTAACATTTCTGAGAGATTTCTTCCAGGCG
AGACGAGAAATACCCATTTCTTATTCATCCAGTAATGCCAATGAAAGAAATCATGAAATCAATGAGTGGACTAAGAGCTTGAAGCACTCAGGATCACTGCTGCTCTGCTGCTTTTACTGCT
GGCACAATGGCGAAGAAAGAAATAACAATTTCTAGCTAAAATCAGGAGTGTGCAATTTGAAGAGCTTTATGCTCCAGAGTACTCAACATTTGACCGCGTGGCTTGGCTTACTCATTTTACTGAA
CCCTACCTCAGTCGAATGGATTGGGTCATACTGTTGATGGGTAATTTTTCTTTAATTCGGAG

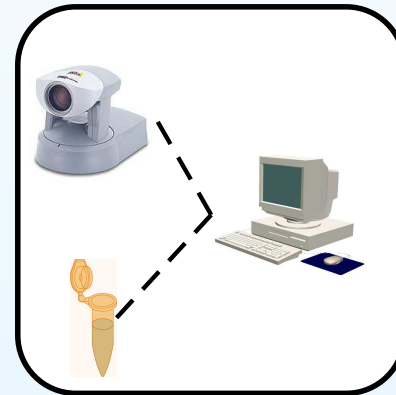
Conclusion

There is no reason anyone would want a computer in their home.

-Ken Olson, president, chairman, and founder of Digital Equipment Corp (1977)

There is no reason anyone wouldn't want a biomachine in their home.

-Austin Che (2005)



The transition from science to engineering is the key to ubiquitous biology technology.

Introduction

Proposal

Need

Impact

- Ethics
- Risk
- Conclusion

Thanks!

Introduction

Proposal

Need

Impact

Thanks!

● Thanks!



*Thanks to the e-ducation without borders
organizing committee!*