CONTACT

Future of Life Sciences:

The great convergence of life and technology

CONTACT 2009

April 3, 2009

Slides: http://slideshare.net/LaBlogga/slideshows

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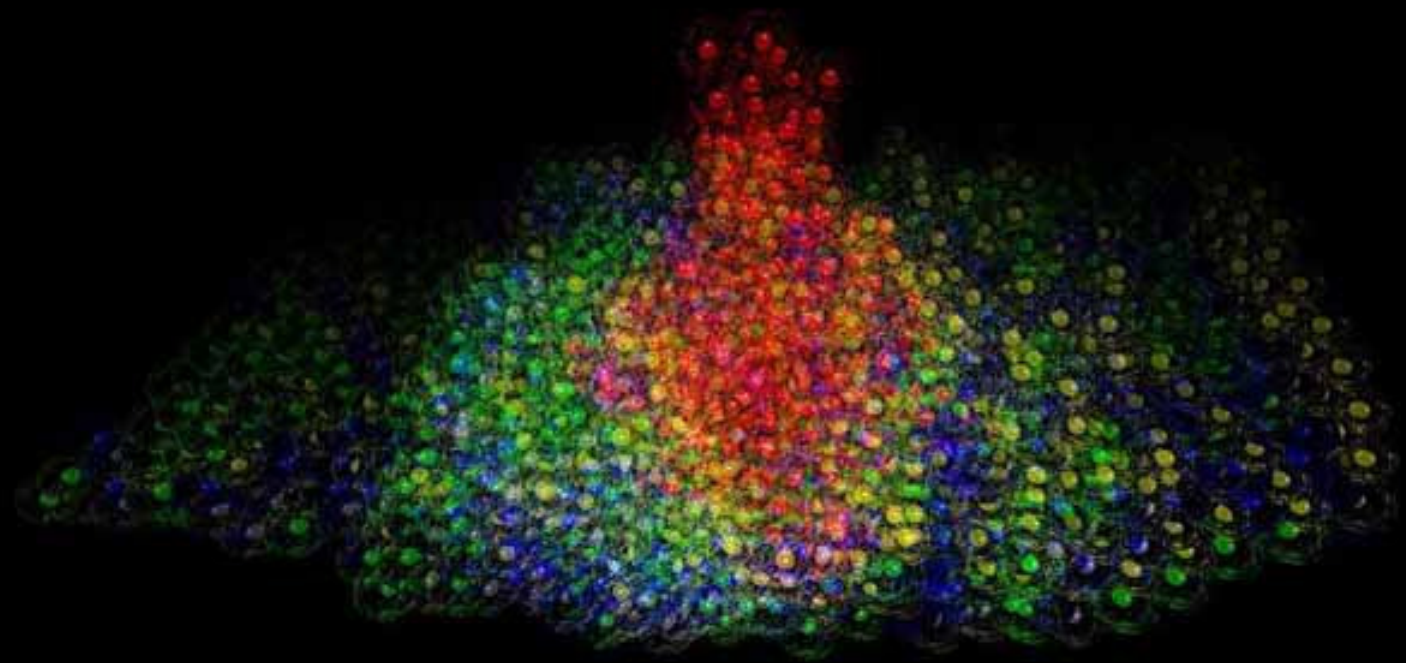
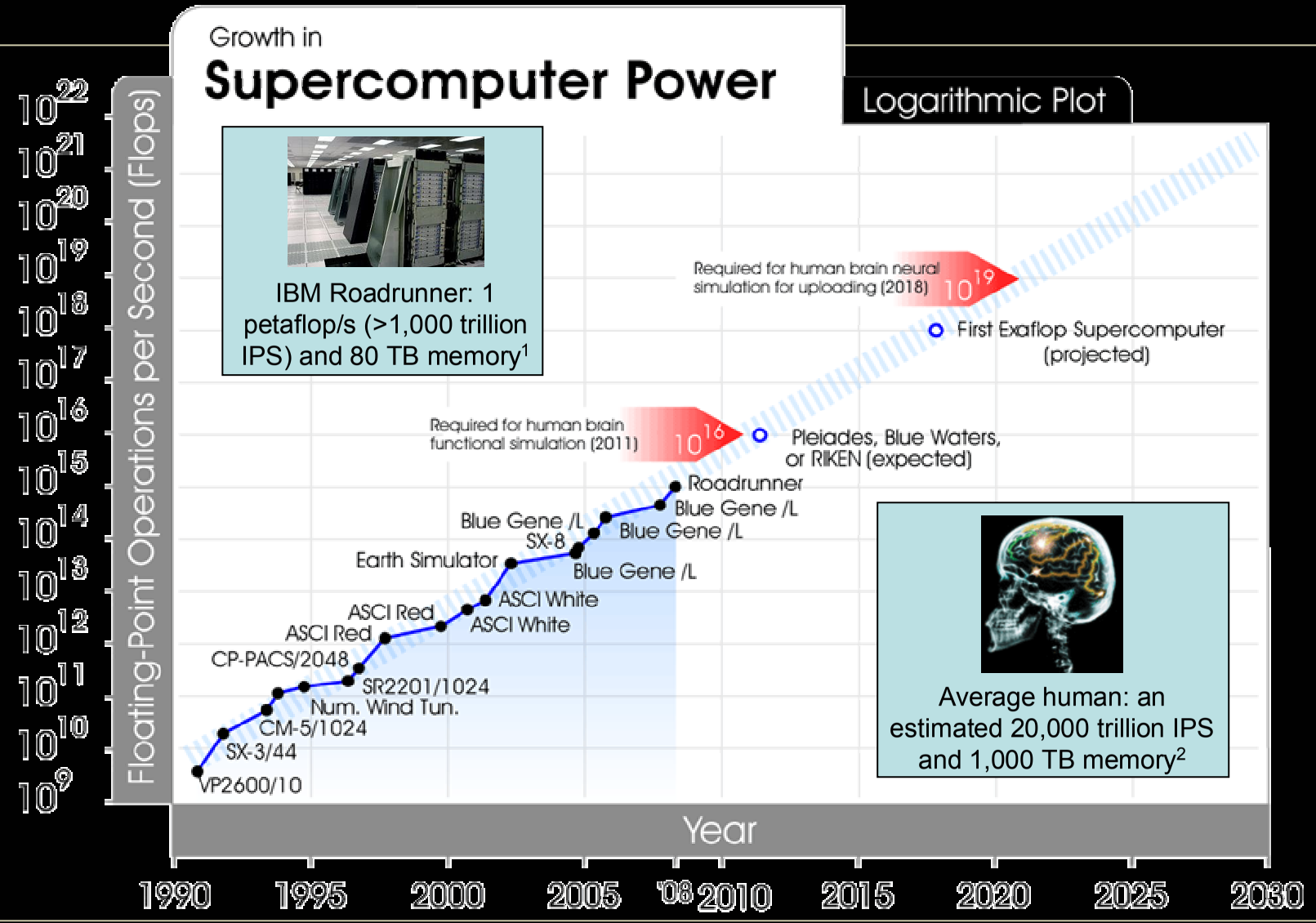
Agenda

1. Introduction: convergence of life and technology
2. Status of relevant high-impact research
3. Future implications



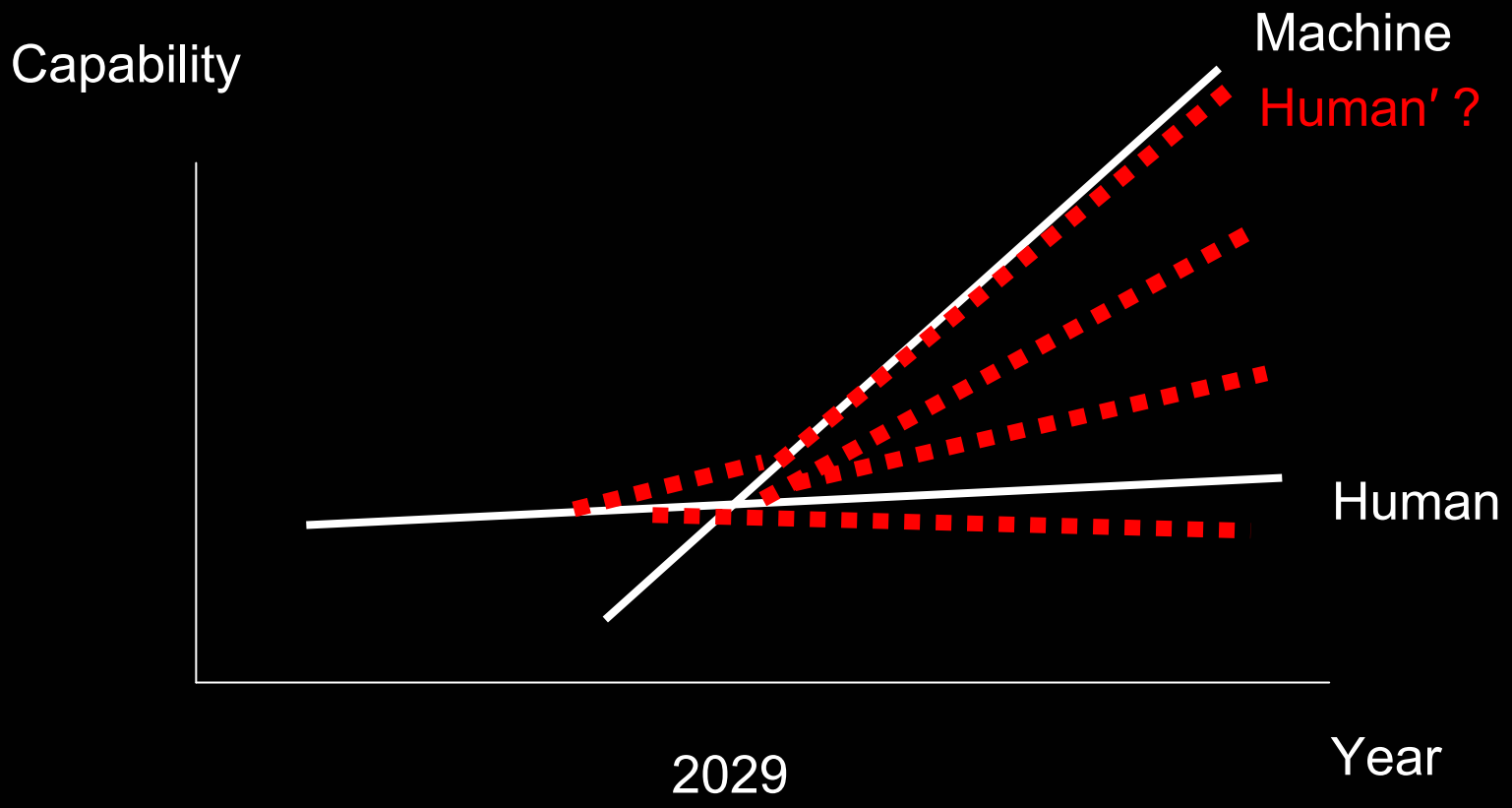
Full human brain neural simulation est: 2018



Source: http://www.kurzweilai.net/pps/Unither
[1]http://www.top500.org/lists/2008/11, http://www.top500.org/system/8968
[2]http://paula.univ.gda.pl/~dokgrk/bre01.html

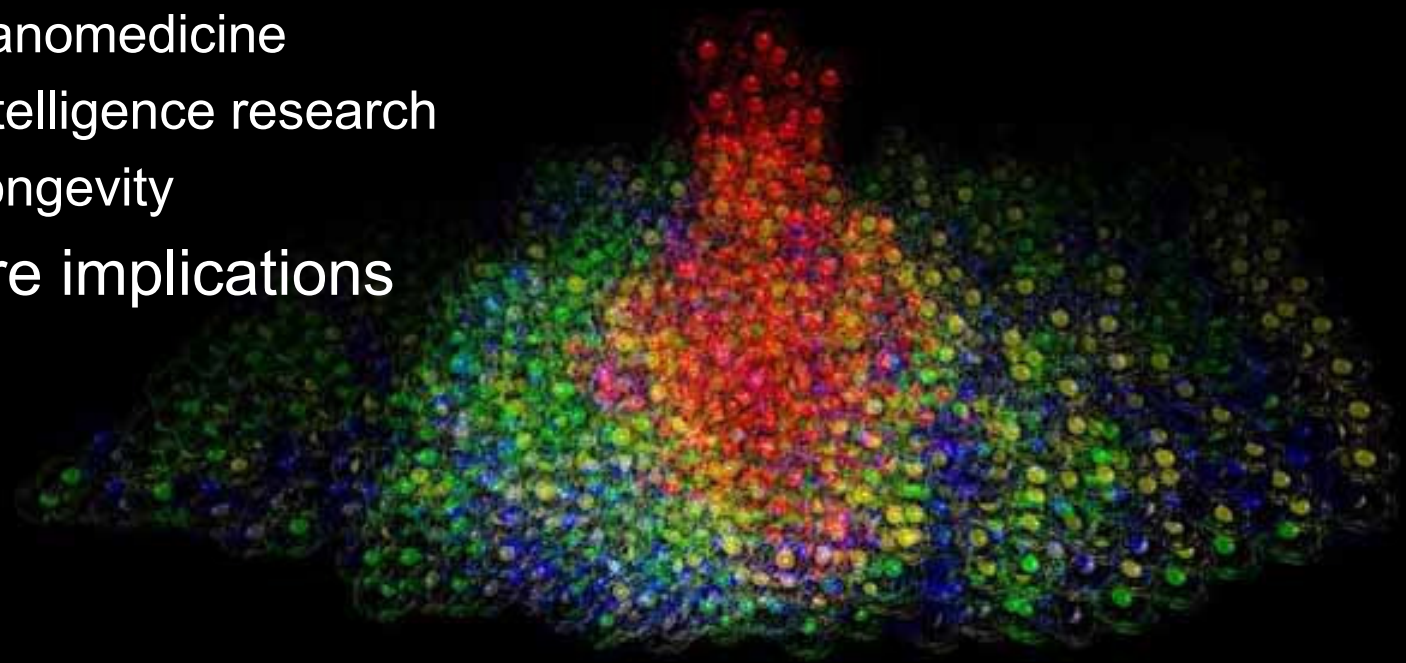
Engineering life into technology

Intelligence convergence: Life and Technology

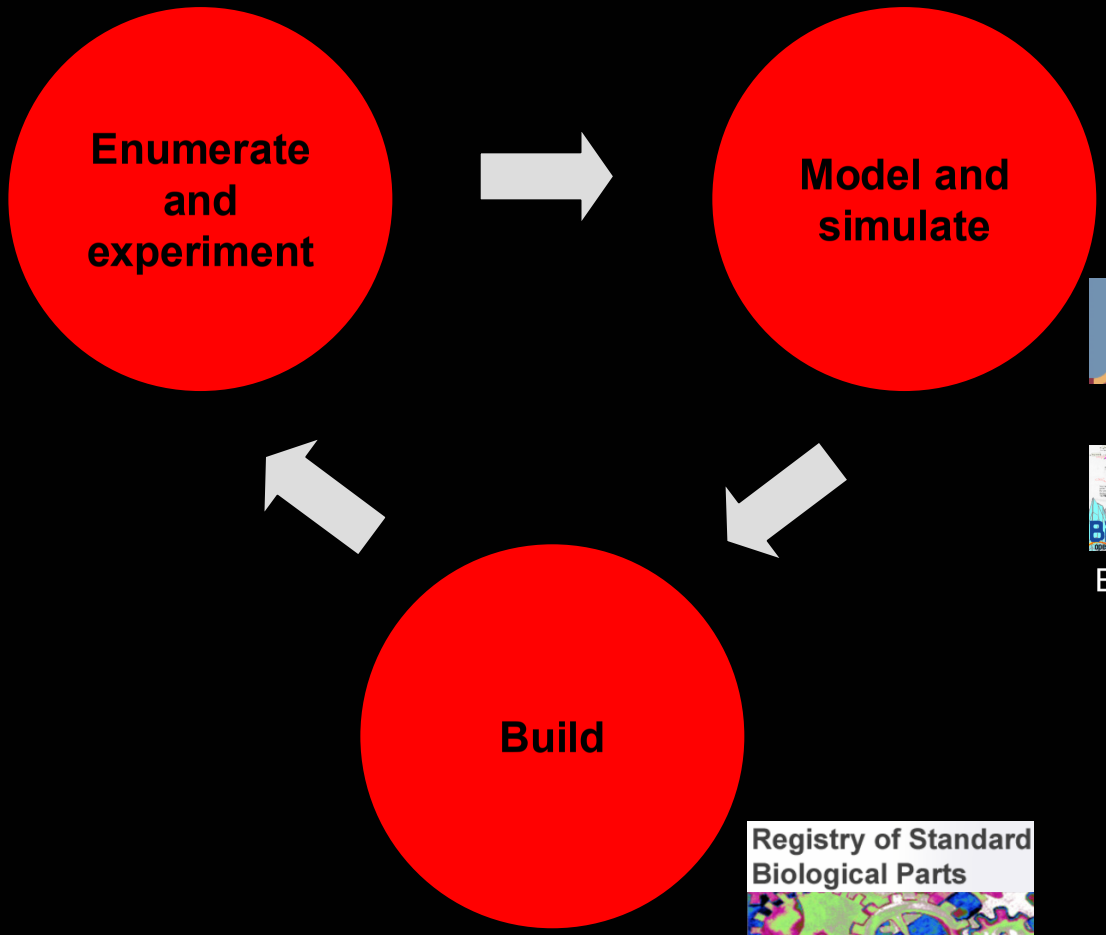


Agenda

1. Introduction: convergence of life and technology
2. Status of relevant high-impact research
   - Evolving concept of life sciences
   - Genomic era
   - Synthetic biology
   - Nanomedicine
   - Intelligence research
   - Longevity
3. Future implications



Evolving concept of life sciences



SimTK.org

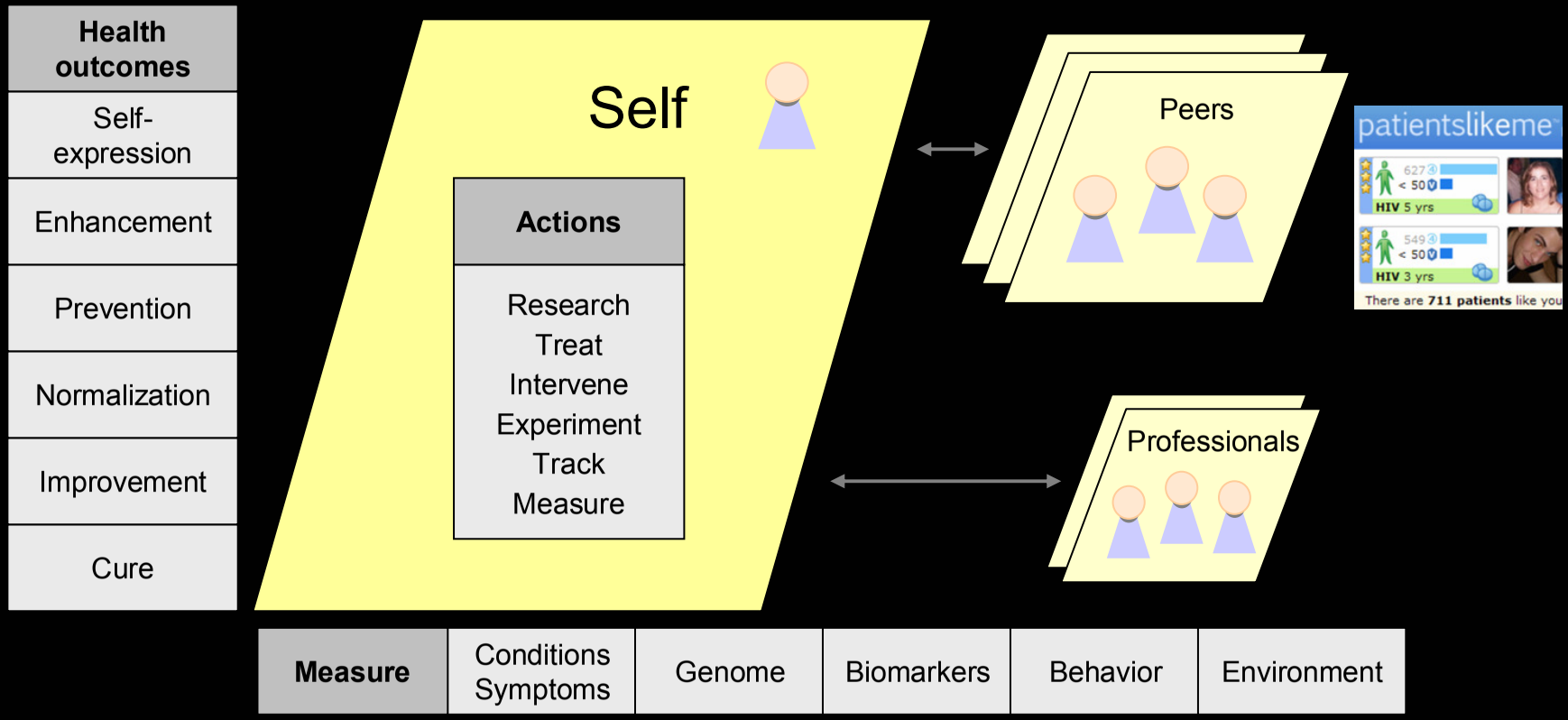
BioSpice.org

Registry of Standard Biological Parts

PartsRegistry.org

Evolving definition of health

A new model of health and health care



Source: http://www.mdpi.com/1660-4601/6/2/492

Evolving computing models

Traditional model

- Linear, von Neumann

Current model extensibility

- New materials
- 3D chip stacking
- Molecular electronics
- Solar transistors

Novel models

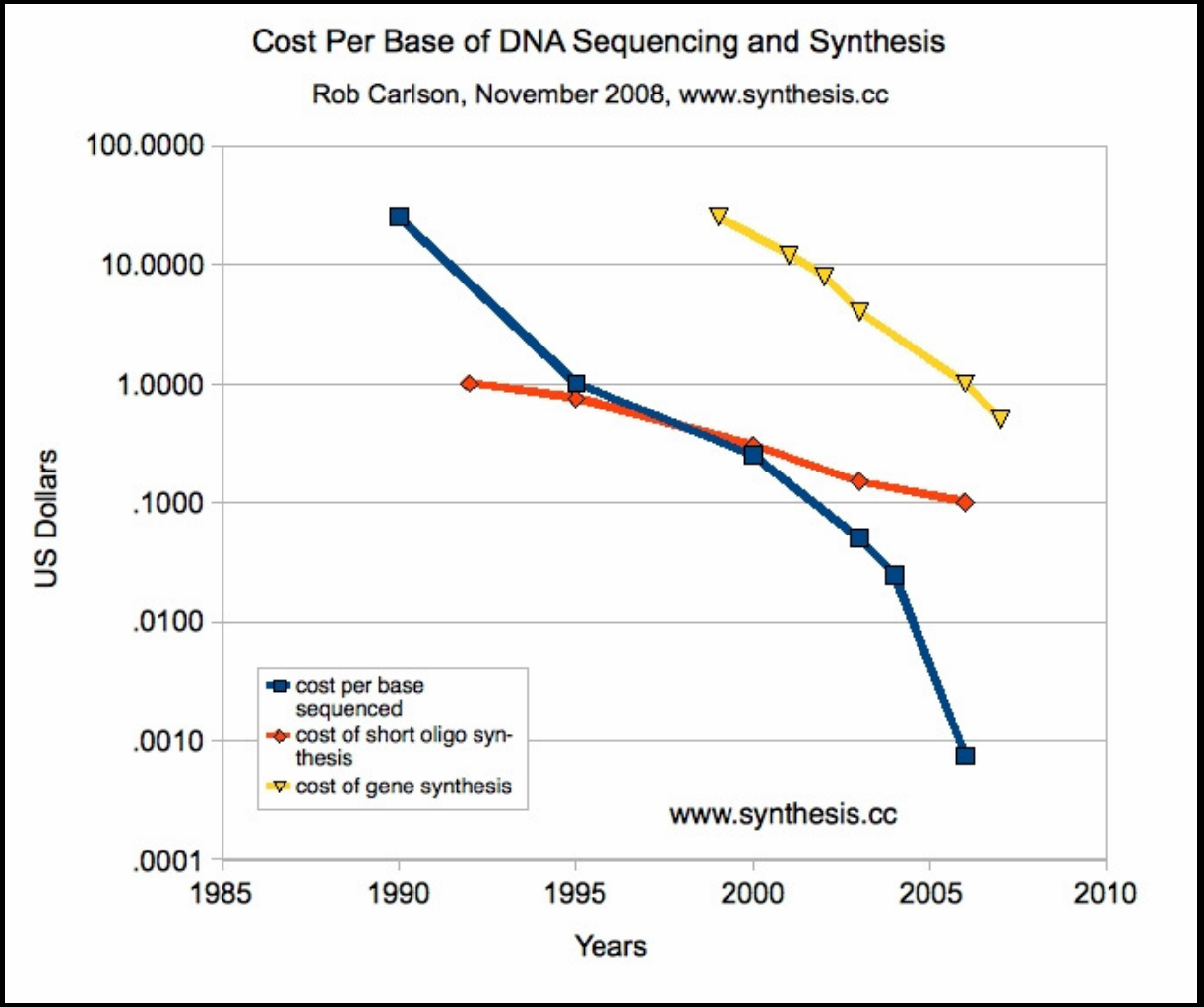
- Parallel
- Cloud, grid, distributed
- Quantum
- Optical computing
- Cell broadband engine
- Liquid computer

Biological models

- DNA nanotech
- DNA computing
- Biosensors
- Cellular colonies
- Bacterial intelligence
- Bioparadigm discovery

Genomic era Carlson curves: 12 mo speedups

- Sequencing
  - (reading)
- Synthesizing
  - (writing)



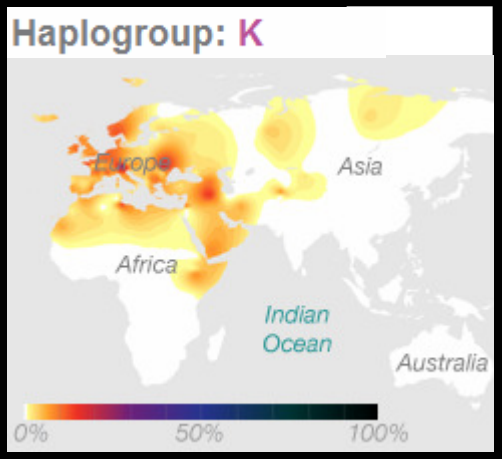
Source: http://www.synthesis.cc/graphics/carlson_cost_per_base_nov_08.jpg

Direct-to-consumer genomics: 23andme

gene journal

580,000 SNPs scanned and mapped to 78 conditions

Age-related Macular Degeneration	Crohn's Disease	Malaria Resistance (Duffy Antigen) new
Alcohol Dependence	Developmental Dyslexia	Male Infertility ♂
Alcohol Flush Reaction	Earwax Type	Measures of Intelligence
Ankylosing Spondylitis	Eye Color new	Memory
Antidepressant Response	Eye Color	Multiple Sclerosis
Atrial Fibrillation	Food Preference	Muscle Performance
Attention-Deficit Hyperactivity Disorder	Freckling	Obesity
Avoidance of Errors	Glaucoma	Obesity
Back Pain	Gout new	Obsessive-Compulsive Disorder ♂
Baldness	HDL Cholesterol Level	Odor Detection
Bipolar Disorder	HIV and AIDS	Pain Sensitivity
Birth Weight	HIV/AIDS Infection	Persistent Fetal Hemoglobin
Bitter Taste Perception	Hair Color	Placental Abruption ♀
Blood Groups new	Heart Attack	Prostate Cancer ♂
Breast Cancer	Height	Restless Legs Syndrome
Caffeine Metabolism	Heroin Addiction	Rheumatoid Arthritis
Celiac Disease new	High Blood Pressure (Hypertension)	Tardive Dyskinesia
Celiac Disease	Lactose Intolerance	Type 1 Diabetes
Cluster Headaches	Longevity	Type 2 Diabetes
Colorectal Cancer	Lou Gehrig's Disease (ALS)	Venous Thromboembolism



# rsid	chromosome	position	
rs3094315	1	742429	AG
rs12562034	1	758311	GG
rs3934834	1	995669	CC
rs9442372	1	1008567	GG
rs3737728	1	1011278	GG
rs11260588	1	1011521	GG
rs6687776	1	1020428	CC
rs9651273	1	1021403	GG
rs4970405	1	1038818	AA
rs12726255	1	1039813	AA
rs11807848	1	1051029	TT
rs9442373	1	1052501	AA
rs2298217	1	1054842	CC
rs12145826	1	1055892	GG

Source: http://www.23andme.com; open source genomes http://www.snpedia.com/index.php/Genomes

23andme colorectal cancer marker

Karen Jacobs

0.21 out of 100

people of European ethnicity who share Karen Jacobs's genotype will get Colorectal Cancer between the ages of 30 and 49.

Average

0.26 out of 100

people of European ethnicity will get Colorectal Cancer between the ages of 30 and 49.

8q24 region **Marker:** rs6983267

This SNP occurs in a hypothetical gene called LOC727677. Little is known about the gene's function; however, it is located in a region of DNA that often acquires extra copies in colorectal cancers. This suggests that the SNP is linked to a change in the activity of a nearby gene that influences cancer development.

One group found that the riskier version of this SNP is associated not only with an increased risk of colorectal cancer, but also with formation of the precancerous adenomatous polyps. This suggests that the SNP is linked to a gene that affects the very early stages of colorectal cancer.

Citations

Haiman et al. (2007) . "A common genetic risk factor colorectal and prostate cancer." *Nat Genet* 39(8):954-6..

Tomlinson et al. (2007) . "A genome-wide association scan of tag SNPs identifies a susceptibility variant for colorectal cancer at 8q24.21." *Nat Genet* 39(8):984-988.

Zanke et al. (2007) . "Genome-wide association scan identifies a colorectal cancer susceptibility locus on chromosome 8q24." *Nat Genet* 39(8):989-994.

Genes vs. Environment

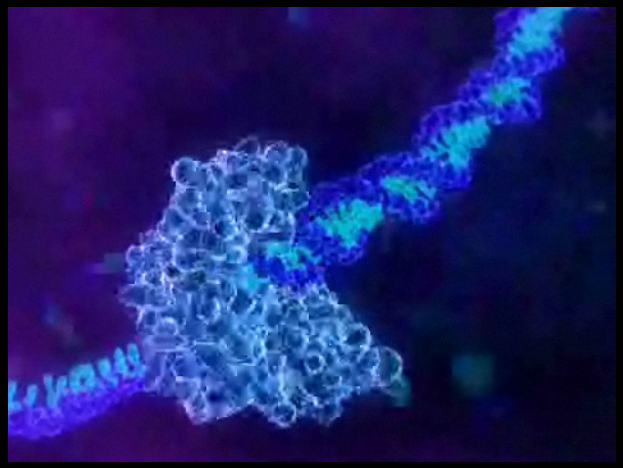
35 %
Attributable to Genetics

The heritability of colorectal cancer is estimated to be 35%. This means that environmental factors contribute more to differences in risk for this condition than genetic factors. Genetic factors that play a role in colorectal cancer include both unknown and known factors. Known factors include rare mutations in the MSH2 and MLH1 genes that appear in familial cases of colon cancer (which 23andMe does not genotype), and the SNP we describe here. Other factors include a history of previous colorectal cancer, colorectal polyps, or inflammatory bowel disease, being an Ashkenazi Jew or of African descent, a diet high in animal fat, physical inactivity, obesity, smoking, heavy alcohol use, and diabetes. (Note: The contribution of the SNP reported by 23andMe to inherited colorectal cancer risk is minor. If you have a strong family history of early-onset colon cancer, you should consider mutation testing of MSH2 and MLH1.) (sources)

Source: http://www.23andme.com

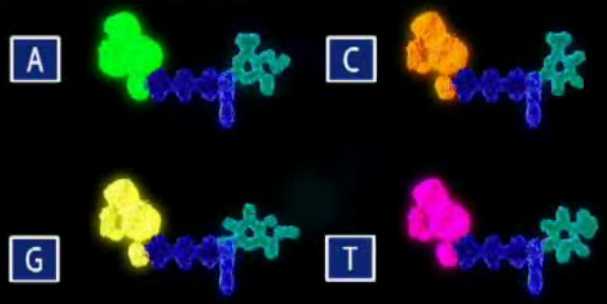
Next-gen sequencing: Pacific Biosciences

1



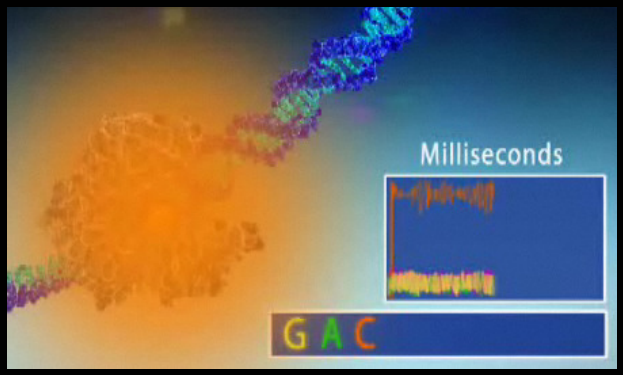
DNA polymerase wrapped around DNA chain

2

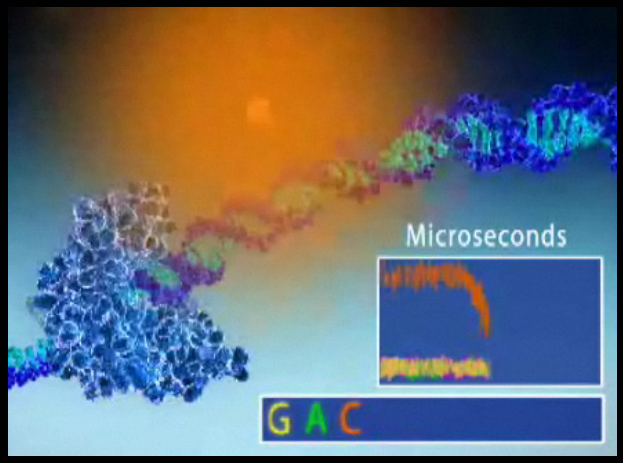


Phospholinked nucleotides

3a



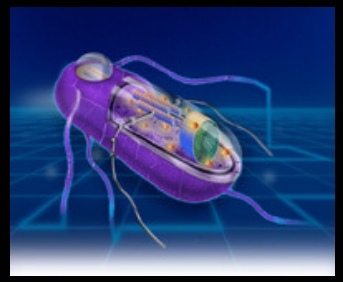
3b

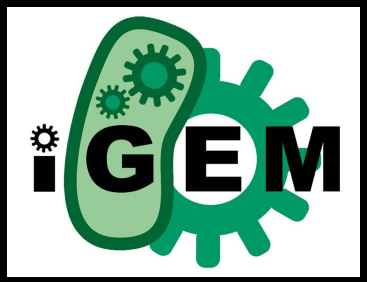


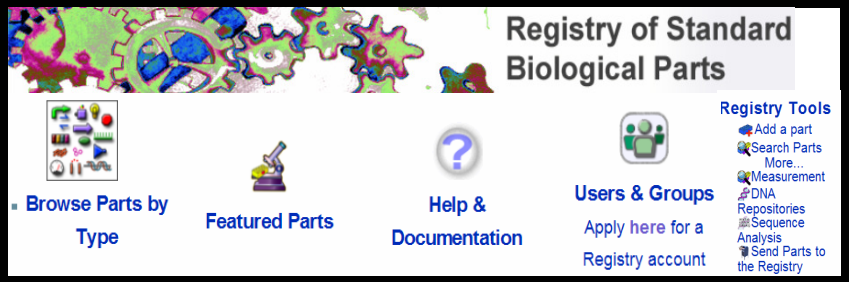
Phospholinked nucleotide binds, fluoresces and detaches as nucleotide base is read

Sources: http://www.pacificbiosciences.com/video_lg.html, http://www.sciencemag.org/cgi/content/abstract/323/5910/133, Science 2 January 2009: Vol. 323. no. 5910, pp. 133 – 138, DOI: 10.1126/science.1162986

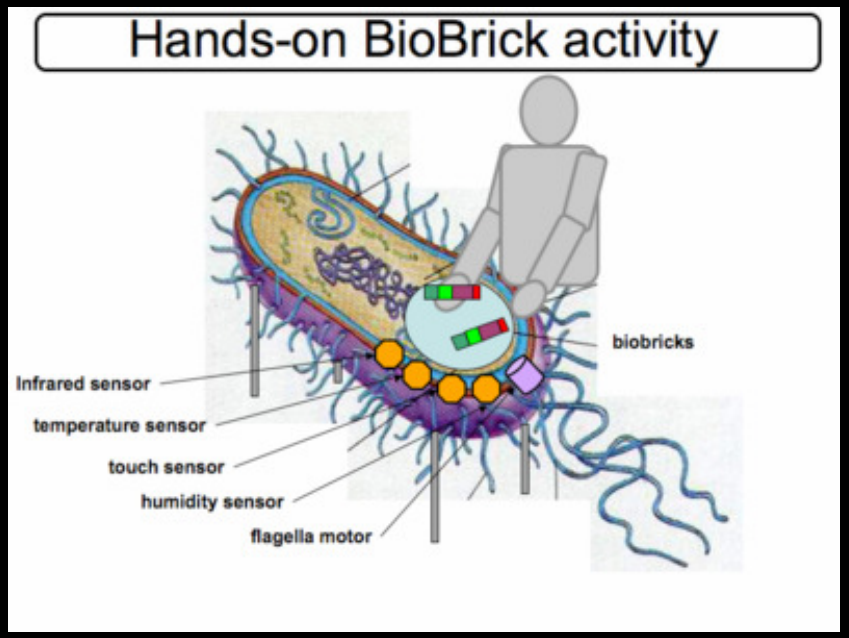
Next-gen biotech: synthetic biology







- Engineering biological systems
  - Parts Registry
  - BioBricks Foundation
  - iGEM competition
- Key work: Drew Endy, Jay Keasling, Craig Venter, Christina Smolke, Tom Knight

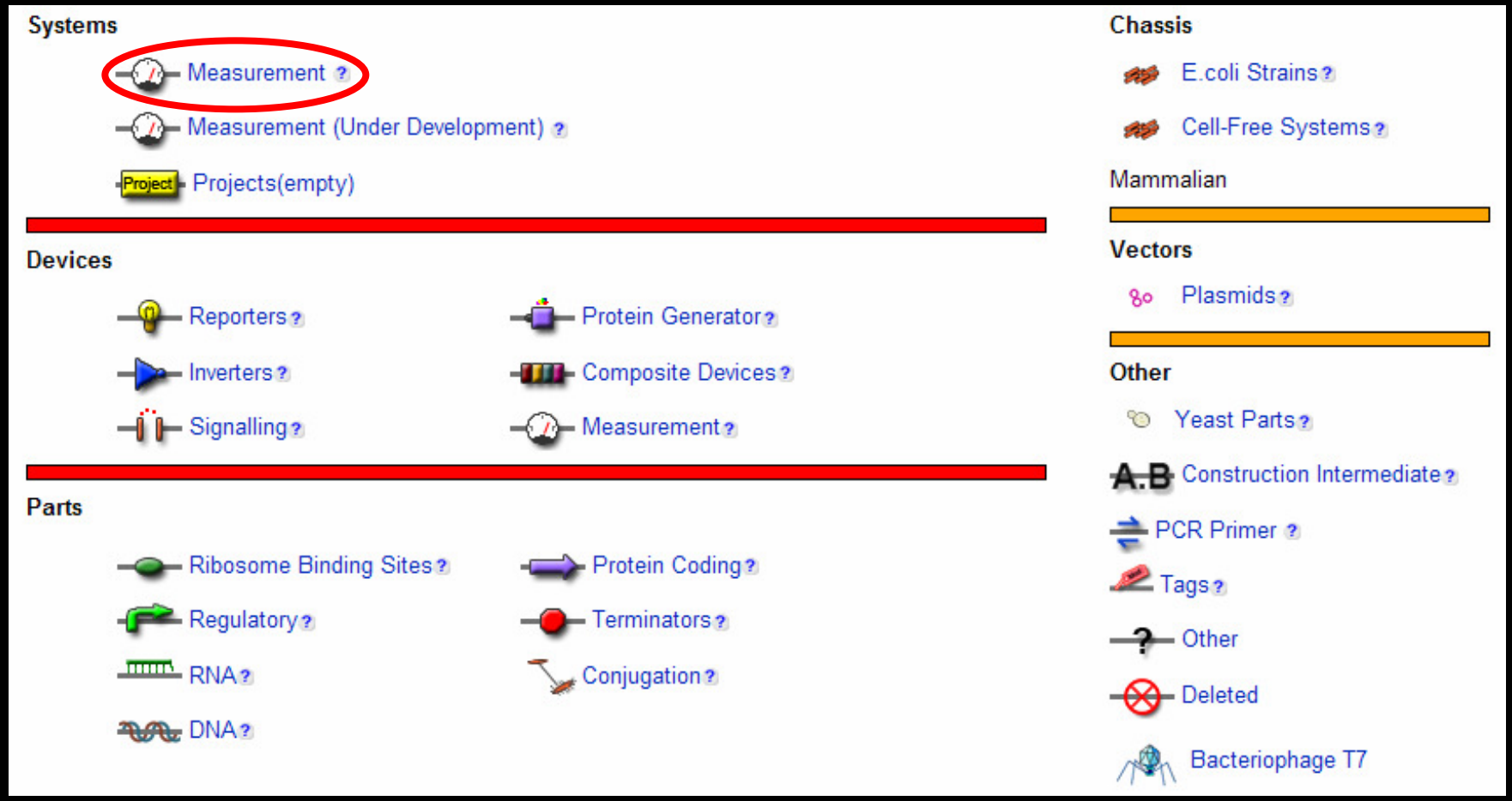


ginkgobioworks

Sources: http://openwetware.org, http://bbf.openwetware.org, http://www.igem.org, http://partsregistry.org

Registry of Standard Biological Parts

- Modular building block components



Source: http://partsregistry.org

Parts Registry: select measurement system

Measurement Devices

Information about measurement systems

Table of promoter output high measurement system parts

Available Measurement Devices *Show 165 more parts* *Edit*

-?-	Name	Type	Description	Output	Length
A W	BBa_I13513	Measurement	Screening Plasmid 2		2885
A W	BBa_I13515	Measurement	Screening Plasmid 4		2825
A W	BBa_I5131	Measurement	[illegible]		906
A W	BBa_I7100	Measurement	TetR repressible GFP generator		940
A W	BBa_I732901	Measurement	[illegible]		3438
A W	BBa_I732902	Measurement	R0010 I732020		597
A W	BBa_I732903	Measurement	R0011 I732020		452
A W	BBa_I732913	Measurement	[aTC] -> RFP		1757
A W	BBa_I732914	Measurement	P_NAND_U073O26D001O16 + RFP		989
A W	BBa_I732916	Measurement	P_NOR_U037O11D002O22 + RFP		954
A W	BBa_I732917	Measurement	P_NOR_U035O44D001O22 + RFP		951
A W	BBa_J5517	Measurement	Arabinose -> LacI ts -| GFP		3473
A W	BBa_J5518	Measurement	Arabinose -> LacI ts -| mRFP		3458
A	BBa_I13008	Measurement	RBS Test R0011.B0031.E0130		942
A	BBa_I13011	Measurement	RBS Test R0040.B0030.E0130		943
A	BBa_I13012	Measurement	RBS Test R0040.B0031.E0130		942
A	BBa_I13013	Measurement	RBS Test R0040.B0032.E0130		941
A	BBa_I13014	Measurement	RBS Test R0040.B0033.E0130		939
A	BBa_I13512	Measurement	Screening plasmid 1		2887
A	BBa_I13514	Measurement	Screening Plasmid 3		2825
A	BBa_I13529	Measurement	Screening Plasmid 2.1		2911
A	BBa_I13530	Measurement	Screening Plasmid 2.2		2911
A	BBa_I13533	Measurement	Screening Plasmid 2.5		2945
A	BBa_I13534	Measurement	Screening Plasmid 2.6		2945
A	BBa_I13606	Measurement	Reporter Construct (Ty+Lc+)		1966
A	BBa_I13614	Measurement	Cascaded Tet (medium) and Lac (medium) QPIs		2284
A	BBa_I13617	Measurement	Cascaded Tet (elowitz) and Lac (medium) QPIs		2282
A	BBa_I13623	Measurement	Cascaded Lac (medium) and Tet (weak) QPIs		2281
A	BBa_I13624	Measurement	Cascaded Lac (medium) and Tet (medium) QPIs		2284

Source: http://partsregistry.org

Parts Registry: obtain and print sequence

Part:BBa_I7100

DNA Available
Experience: Works

Designed by Jennifer Braff

Entered: 2004-10-26

TetR repressible GFP generator

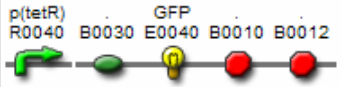
BBa_I7100 is a composite part consisting of a TetR repressible promoter (BBa_R0040) and a GFP generator (BBa_E0840). Thus, BBa_I7100 produces fluorescence in either the absence of TetR or in the presence of the inducer aTC.

Usage and Biology

See BBa_R0040 for details on the TetR repressible promoter.

Sequence and Features

Format: Subparts | Ruler | SS | DS Search: Length: 940 bp Context: Part only Get selected sequence



Part-only sequence for BBa_I7100(940 bp)

```
tccctatcagtgatagagattgacatccctatcagtgatagagatactgagcactactagagattaaagaggagaaatactagatgcgtaaaggagaaga
acttttcactggagttgtcccaattcttgttgaattagatggtgatgttaatgggcacaaattttctgtcagtggagagggtgaaggtgatgcaacatac
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cacactggctcaccttcgggtgggcctttctgcgtttata
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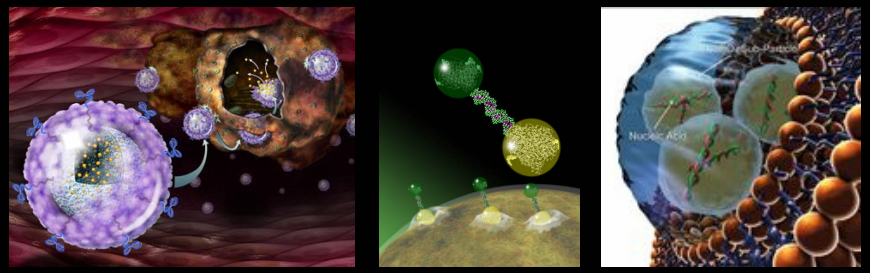
DNA Synthesizer

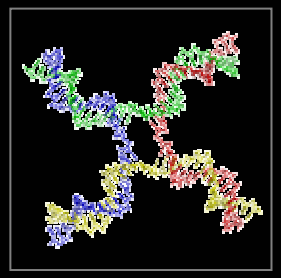
Source: http://partsregistry.org

Nanomedicine

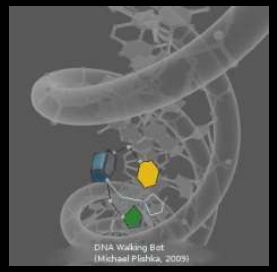
- Nanoparticles
- DNA nanotechnology
  - DNA walker
- Programmable matter
  - Quantum dots
- Nanomachines



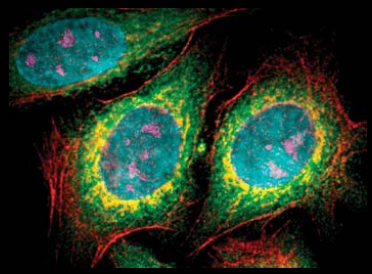
Nanoparticles



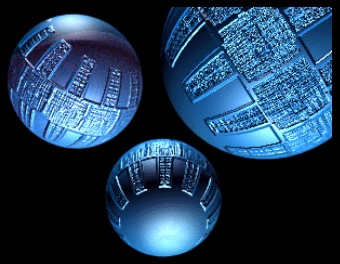
Structural DNA: Holliday junction



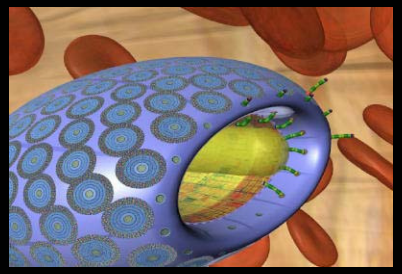
DNA walker



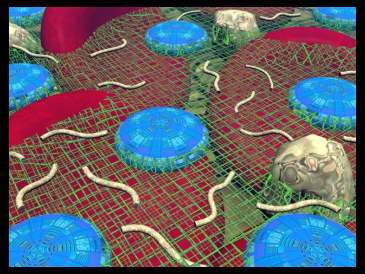
Quantum dot dyes



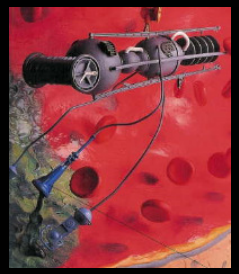
Respirocytes



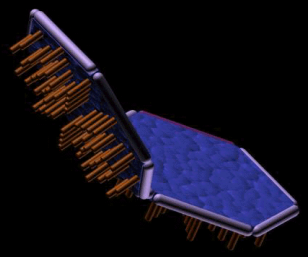
Microbivore



Clottocytes



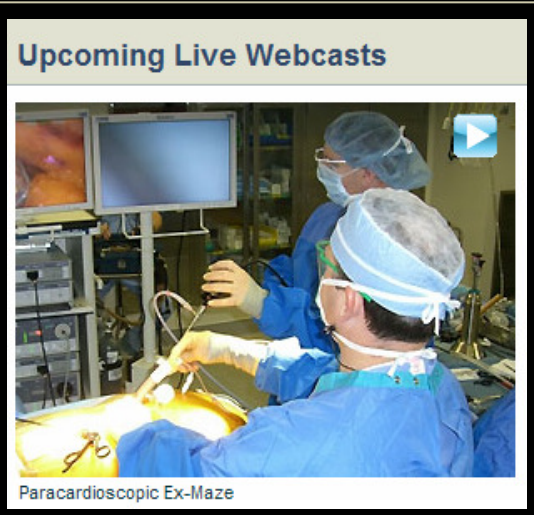
Artery cleaner



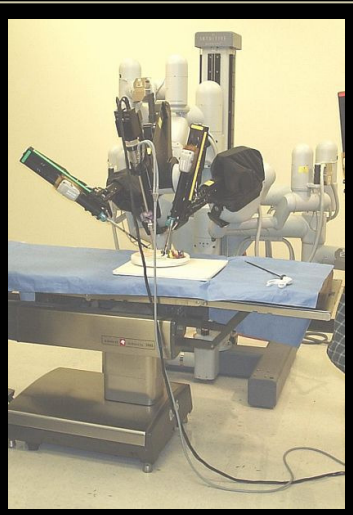
Vasculocyte

Sources: Nanoparticles: http://www.unithertechnologyconference.com
DNA Nanotechnology: http://www.pnas.org/content/101/3/717.full.pdf
Nanorobots: http://www.foresight.org/Nanomedicine/gallery/index.html#ExhibitCat

Radiosurgery and on-demand physicians

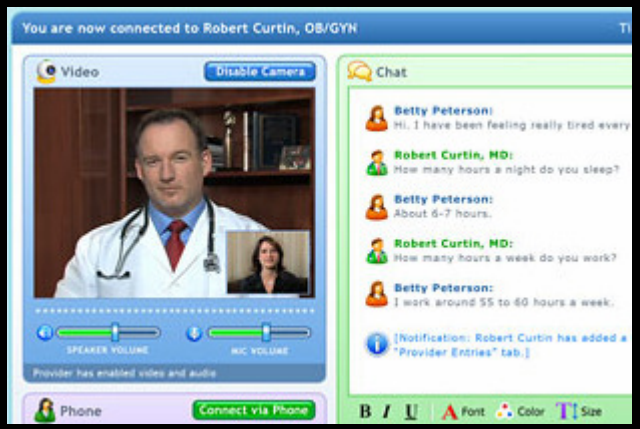


OR-Live.com



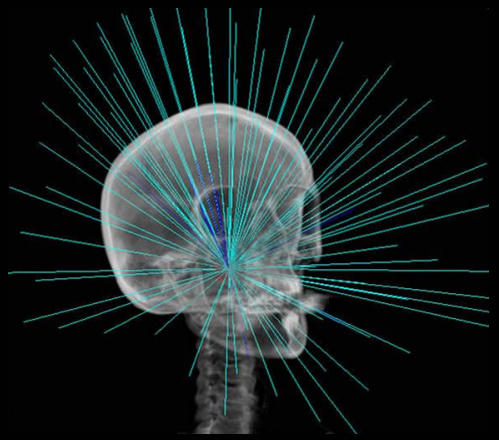
da Vinci Robotic Surgery

Accuray cyberknife radiosurgery



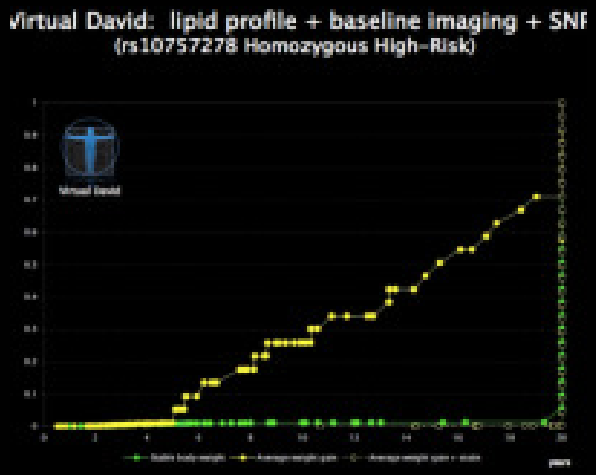
On-demand consultation: American Well

Teleradiology

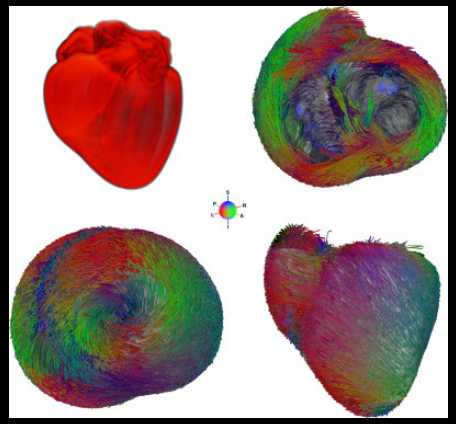


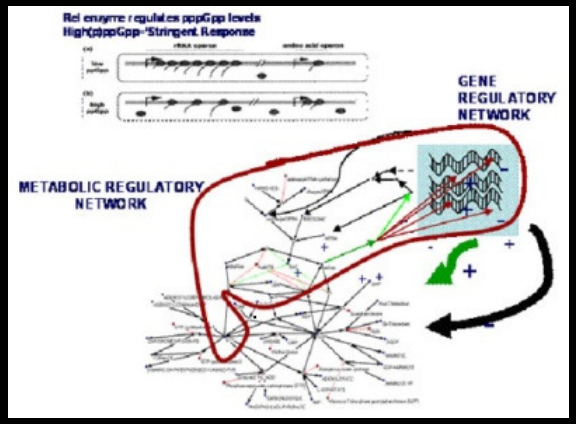
Accuray radiosurgery delivery path

Simulation, modeling and virtual health

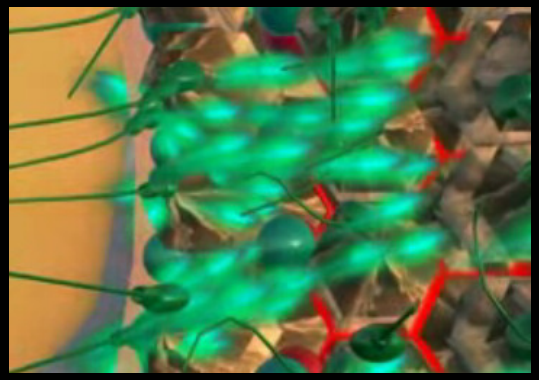


Entelos virtual patient biosimulation





BioSPICE open source simulation software



Testis tour: OSU Medicine

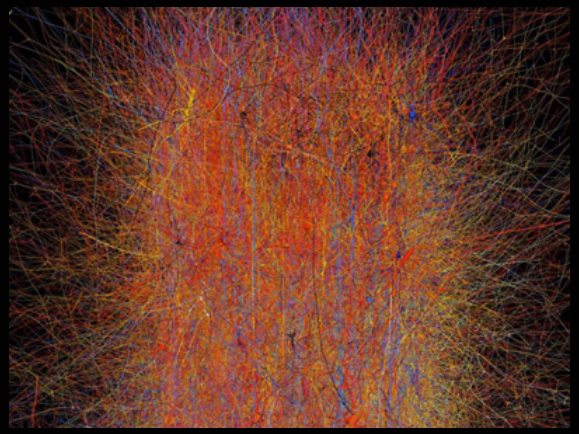
Virtual hospital: Palomar West

Second Health Operating Theatre

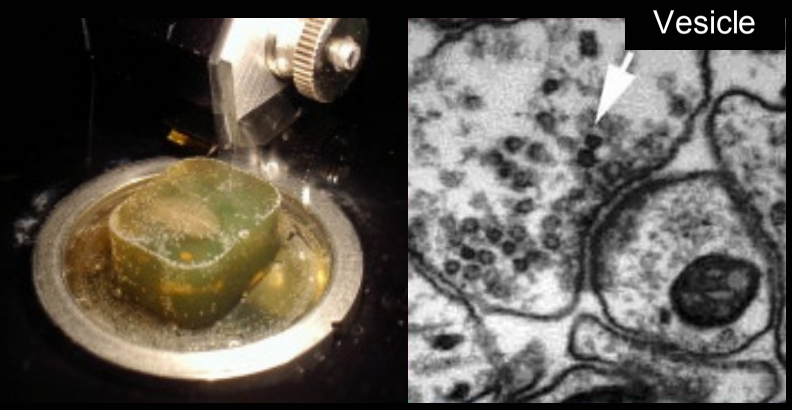
Sources: http://biospice.org, http://www.youtube.com/watch?v=O1YuRSyzBAE, secondlife://PalomarWest%20Hospital/36/125/34/, secondlife://NHS%20London/248/11/26

Intelligence research by approach

- Computer simulation
  - Cortical column simulation
  - Whole brain emulation
- Neuroimaging & connectomics
  - KESM tissue volumes
- Integration
  - Brain-computer interfaces (BCIs)
  - Body area networks (BANs)
    - IEEE standard 802.15.6
- Robotics and AI



Blue Brain rat cortical column

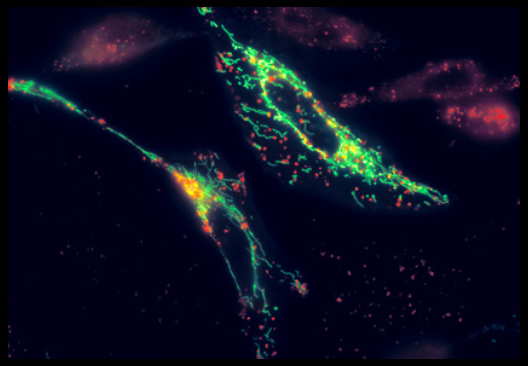


Mouse brain block and cortex slice

Sources: http://seedmagazine.com/content/article/out_of_the_blue, http://www.mcb.harvard.edu/lichtman/ATLUM/ATLUM_web.htm, http://research.cs.tamu.edu/bnl/kesm.html

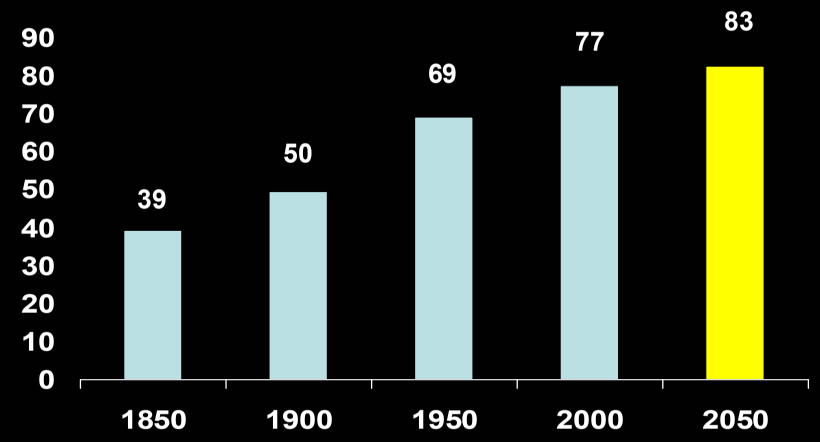
Longevity: extending lifespan and healthspan

- Aging as a multidisciplinary pathology
- Aubrey de Grey: Strategies for Engineered Negligible Senescence (SENS)
  - Nucleic and mitochondrial mutations
  - Intracellular and extracellular junk
  - Cell loss and senescence
  - Extracellular crosslinks
- Solutions and escape velocity
  - Biomedical remediation
  - Mutation anti-suppressors
  - Cell strengthening
- RealAge.com estimation tests



LysoSENS: stained lysosomes

U.S. Life Expectancy, 1850 – 2050e

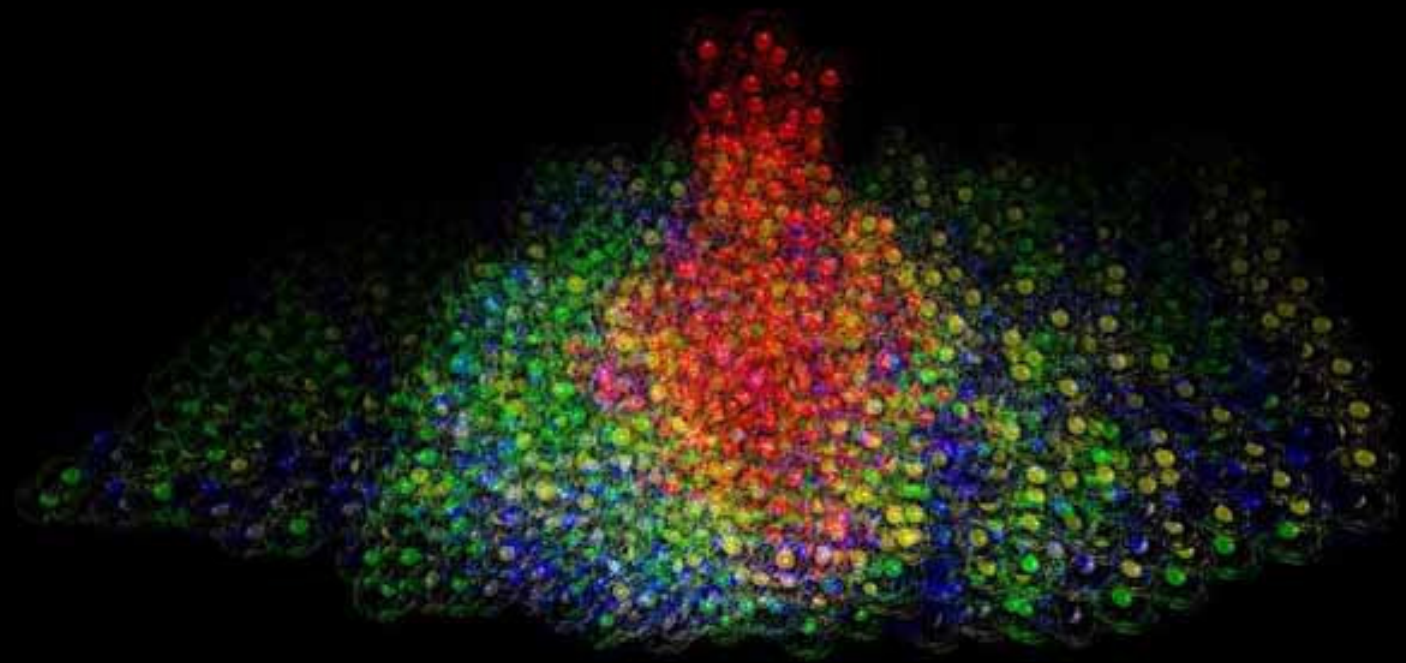


Source: http://www.infoplease.com/ipa/A0005140.html
Source: http://earthtrends.wri.org/text/population-health/variable-379.html

Sources: http://www.mfoundation.org/index.php?pagename=mj_sens_sens, http://pimm.wordpress.com/2007/09/03/sens3-program-john-schloendorn-medical-bioremediation, http://www.mfoundation.org/files/sens/manu16.pdf, http://www.lmrf.org/LysoSENS.html

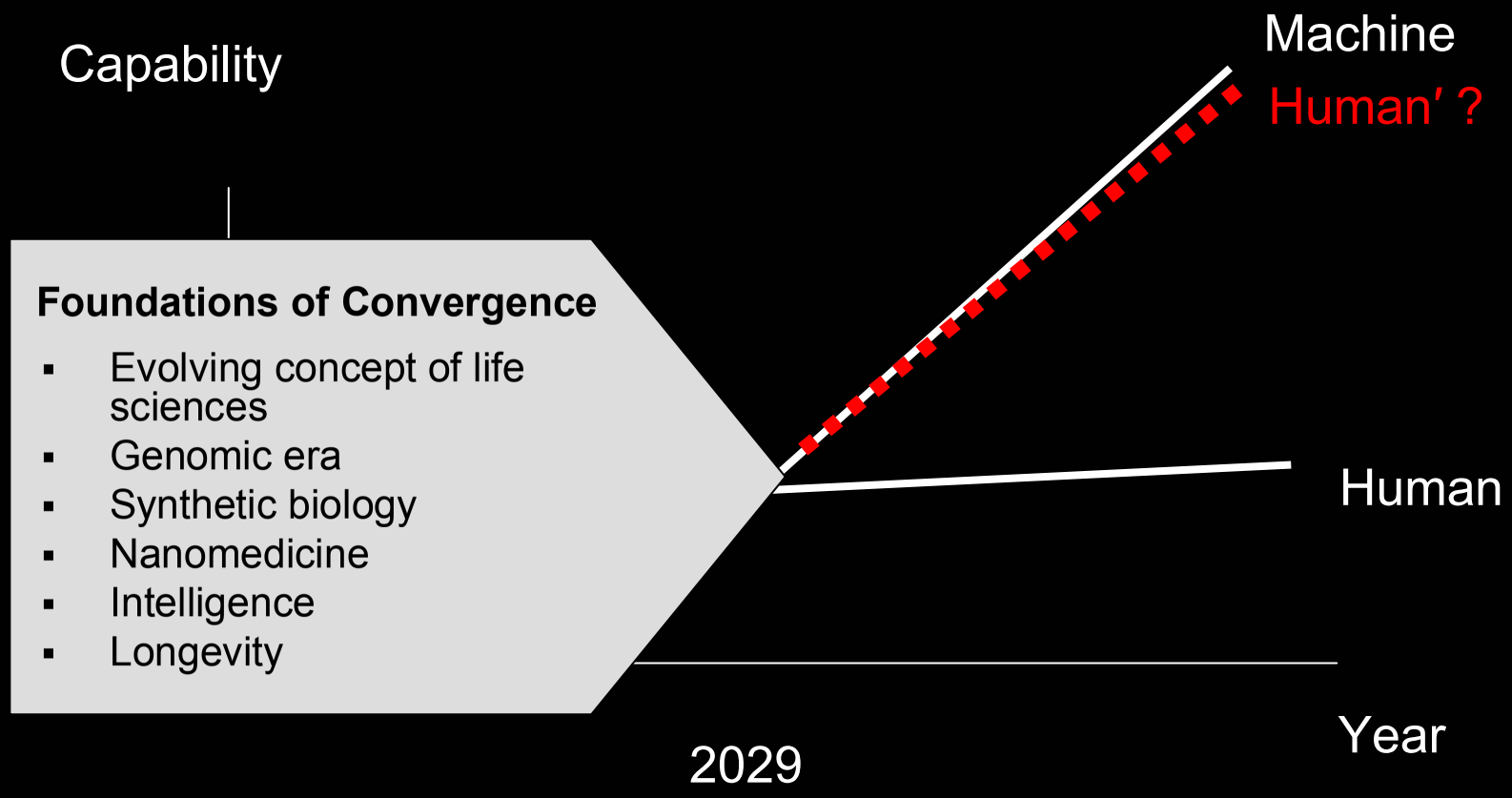
Agenda

1. Introduction: convergence of life and technology
2. Status of relevant high-impact research
3. Future implications



Engineering life into technology

Convergence: Life and Technology



What can be expected in the short-term?

- Onboard computation and communication
- Whole human genome scan
  - Era of personalized medicine
- Next-gen biotech, the new cleantech
  - Focus on key cures: obesity, cancer
- Peer-to-peer health
  - Health social networks
  - Long tail of medicine
- Culture of biohacking

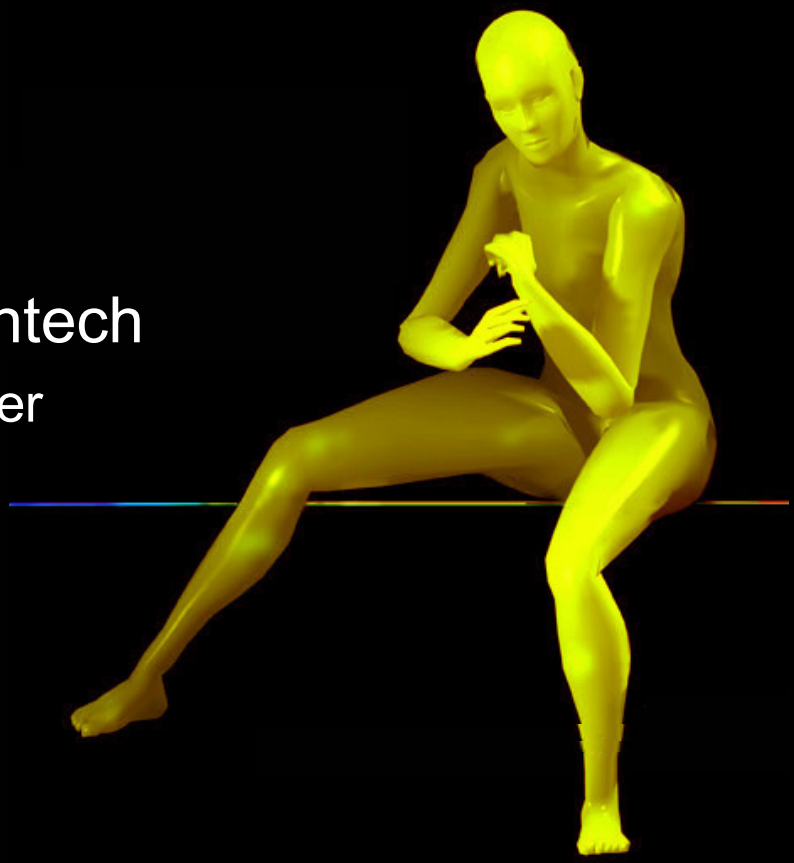
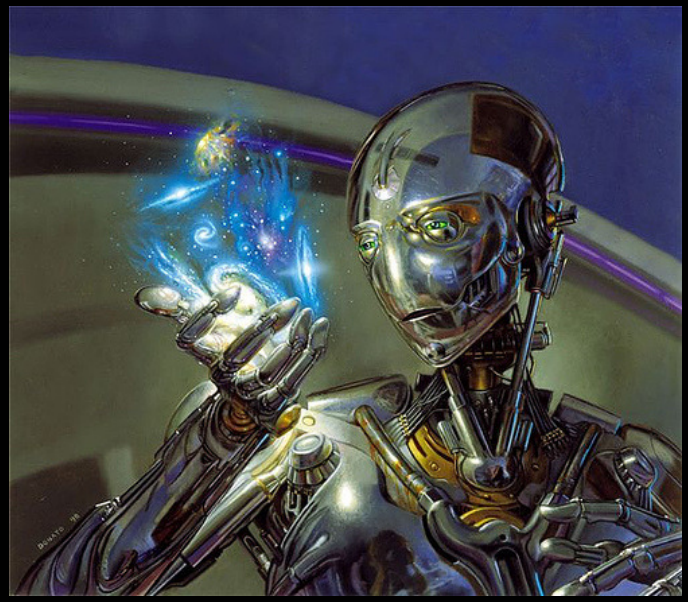


Image: Natasha Vita-More, Primo Posthuman

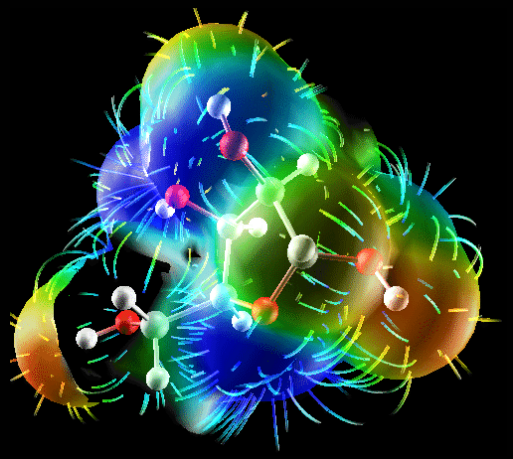
Ultimate possibilities for life and technology

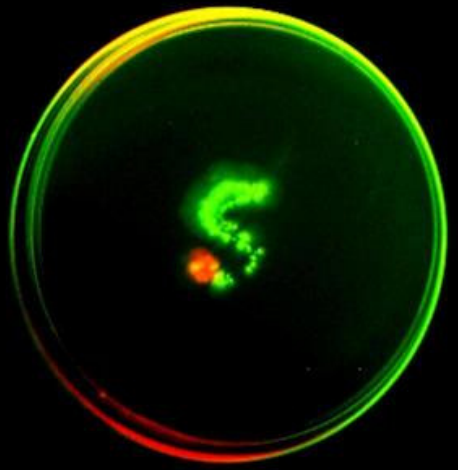
- All matter (including life) designed to spec
  - Purpose-driven form factor, elective embodiment
- Issues
  - Multiple persistent copies
  - Transhumanism, posthumanism
  - Utility functions and emotion
  - Intelligence
  - Ultimate possibilities for life and technology once joined?
    - Aesthetics?
    - Analytics?



Resources

- Conferences, podcasts and video
  - http://www.unithertechnologyconference.com
  - http://www.usc.edu/medicine/bcc
  - http://www.cs.duke.edu/~reif/FNANO
  - http://www.onemedplace.com
  - http://www.or-live.com
- Journals, news, blogs, advocacy groups, etc.
  - http://www.nature.com/nbt/index.html
  - http://www.nbtc.cornell.edu
  - http://www.eyeonDNA.com
  - http://phylogenomics.blogspot.com
  - http://www.personalizedmedicinecoalition.org
- Ethics and biotechnology industry watch groups
  - http://www.bioethics.net (American Journal of Bioethics)
  - http://www.etcgroup.org





Thank you

Slides: http://slideshare.net/LaBlogga/slideshows

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