



Econ of Nano & AI

Robin Hanson
George Mason University

Outline

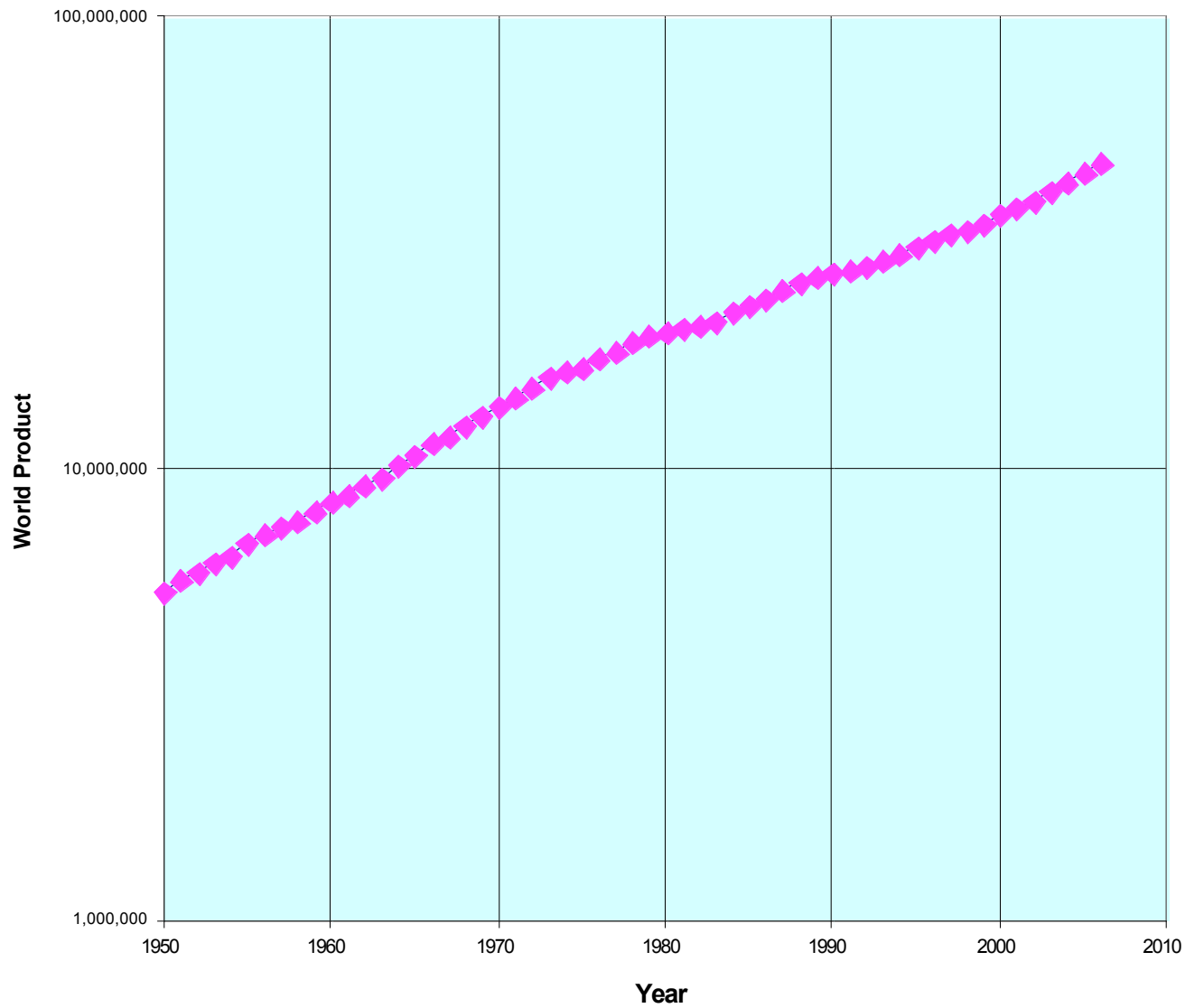
- World long-term econ trend mostly steady
 - Now doubles in ~15 years
- So far have seen 2-4 “singularities” when
 - World econ growth rate increased x150-250
 - In much less than a previous doubling time
- Next?: by 2100, takes 5 yr, double monthly
 - Nanotech?
 - Artificial Intelligence?

Recent US GDP Growth

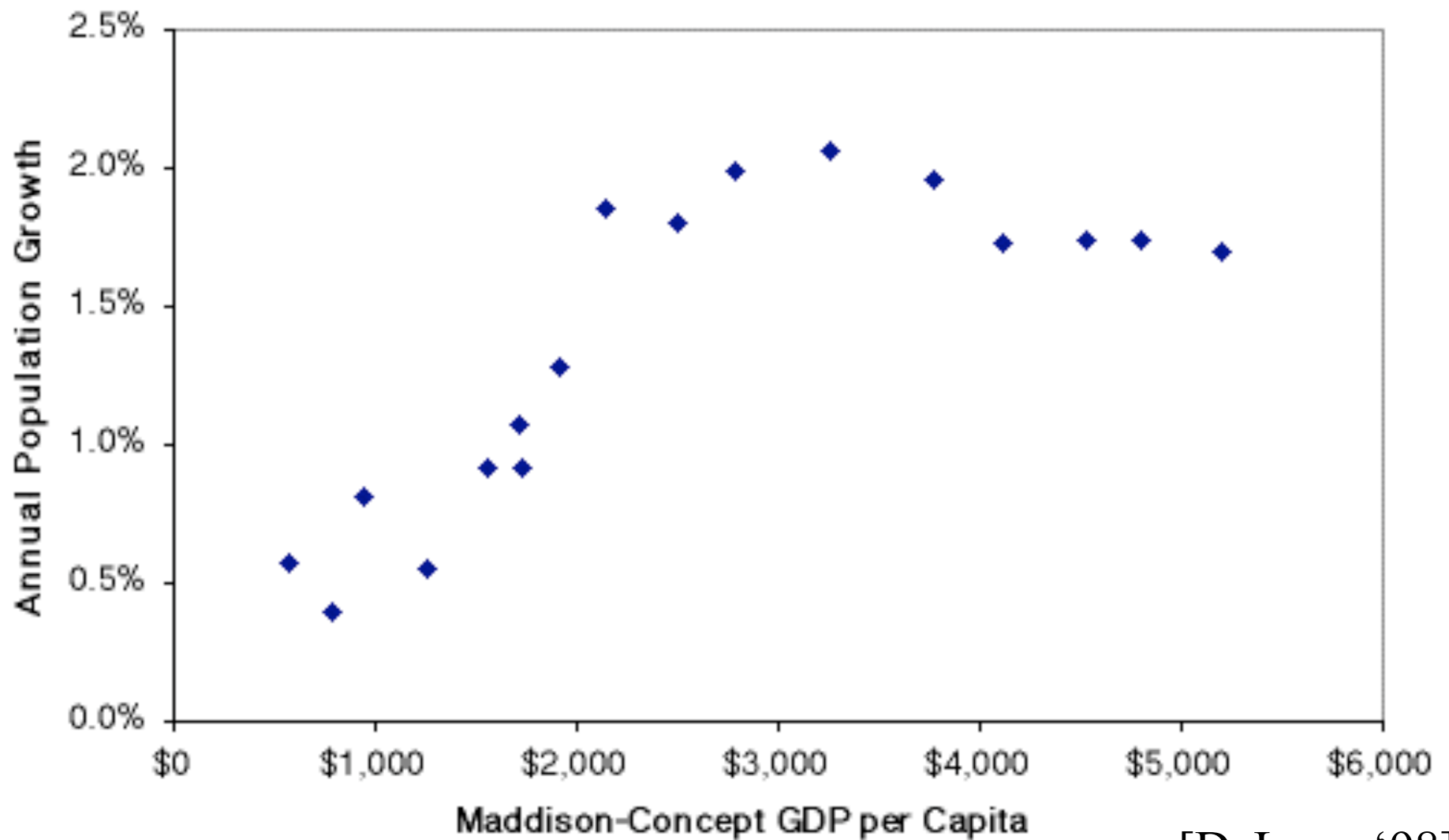


Real GDP growth is measured at seasonally adjusted annual rates.

World Product, 1950-2006

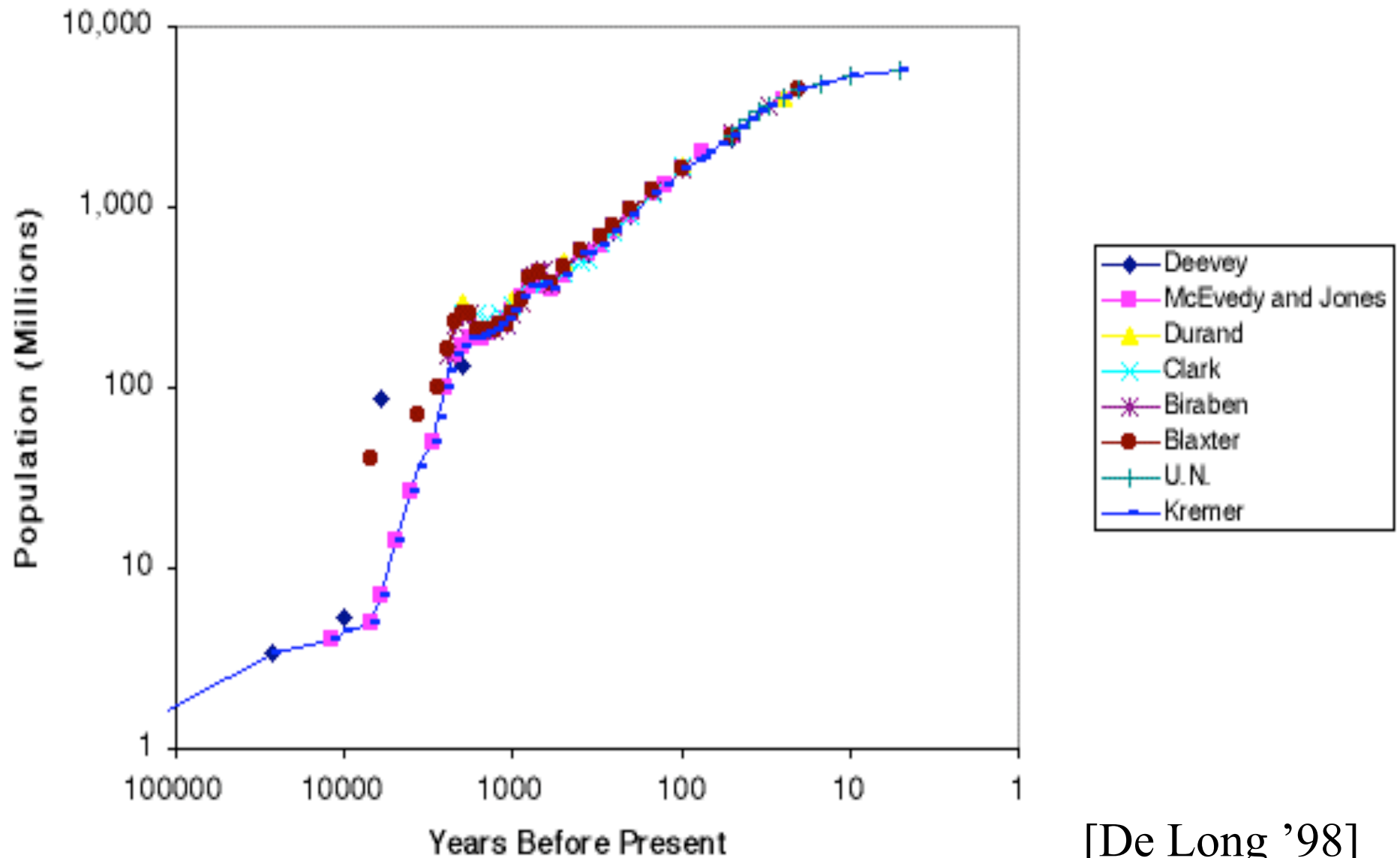


Population Growth and Maddison-Concept GDP per Capita Since 1820



[DeLong '98]

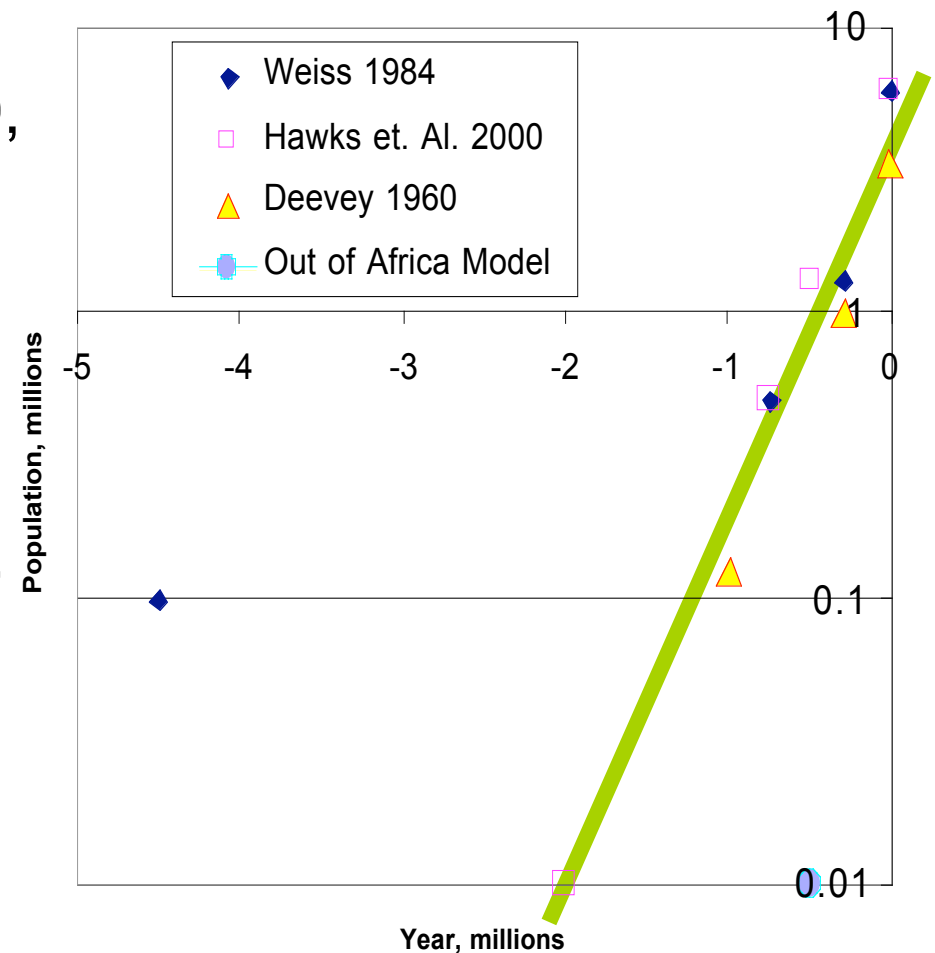
Historical Human Populations



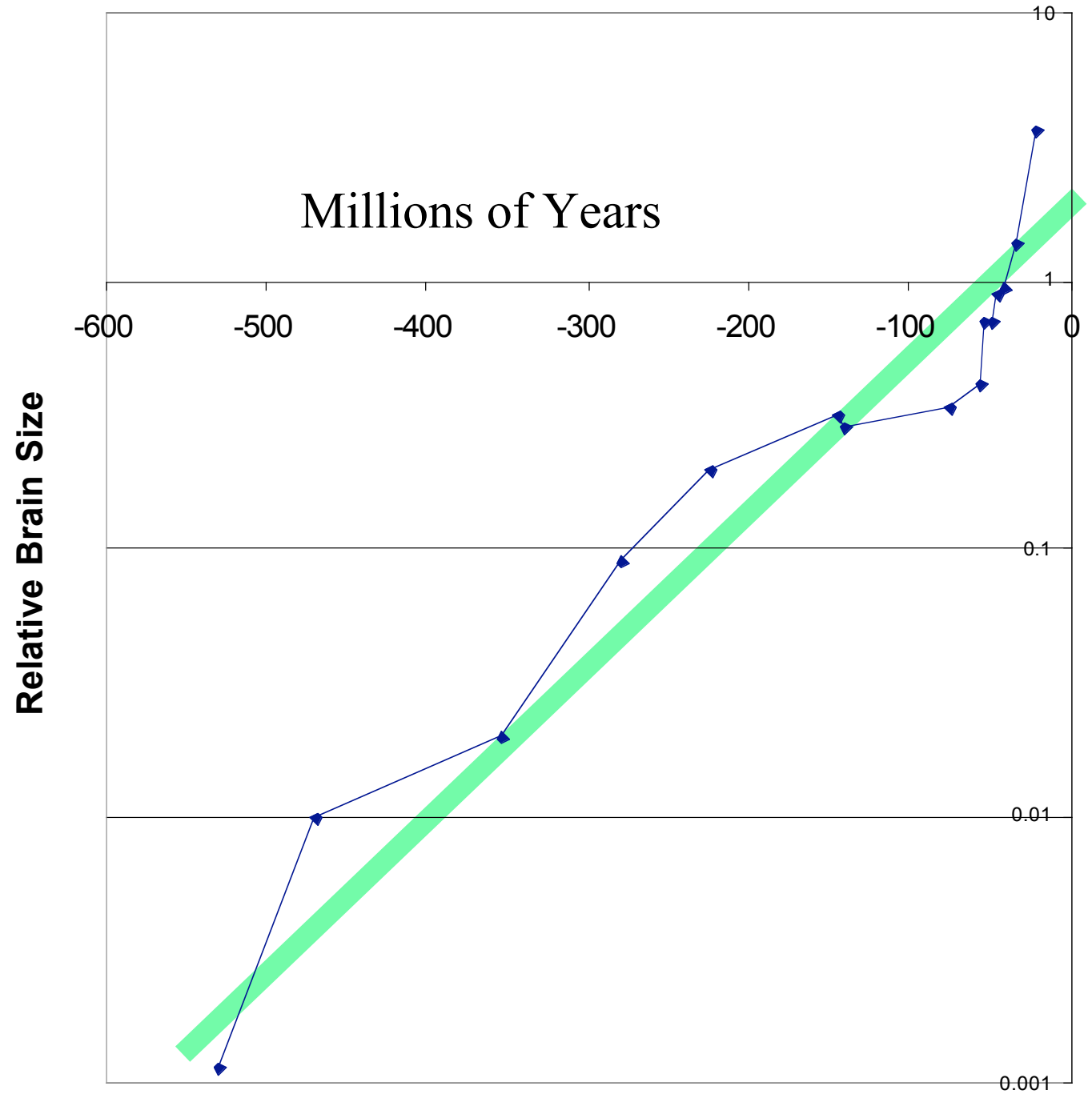
[De Long '98]

PaleoDemography

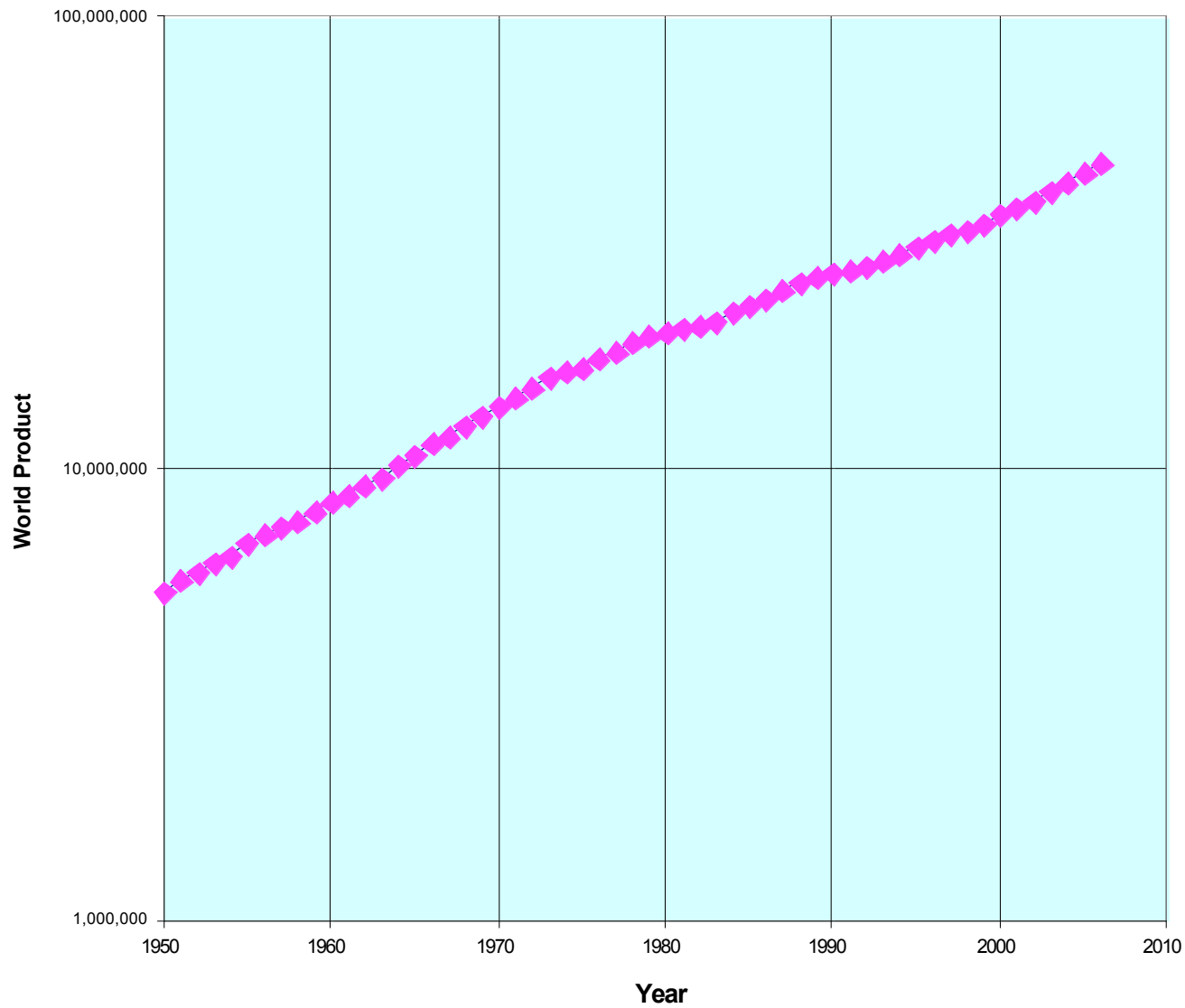
- DeLong 98 follows Kremer 93 in using Deevey 60 est.
- I substitute Hawks et al. 00, who posit exp. pop. growth from $\sim 10K$ 2MYA.
- Based on Multi-regional model (vs. Out of Africa)
- 2MYA - simul., signif. new size, pelvis, brain, teeth, ...
- DNA says inbreeding pop $\sim 10K$, before 1.5MYA



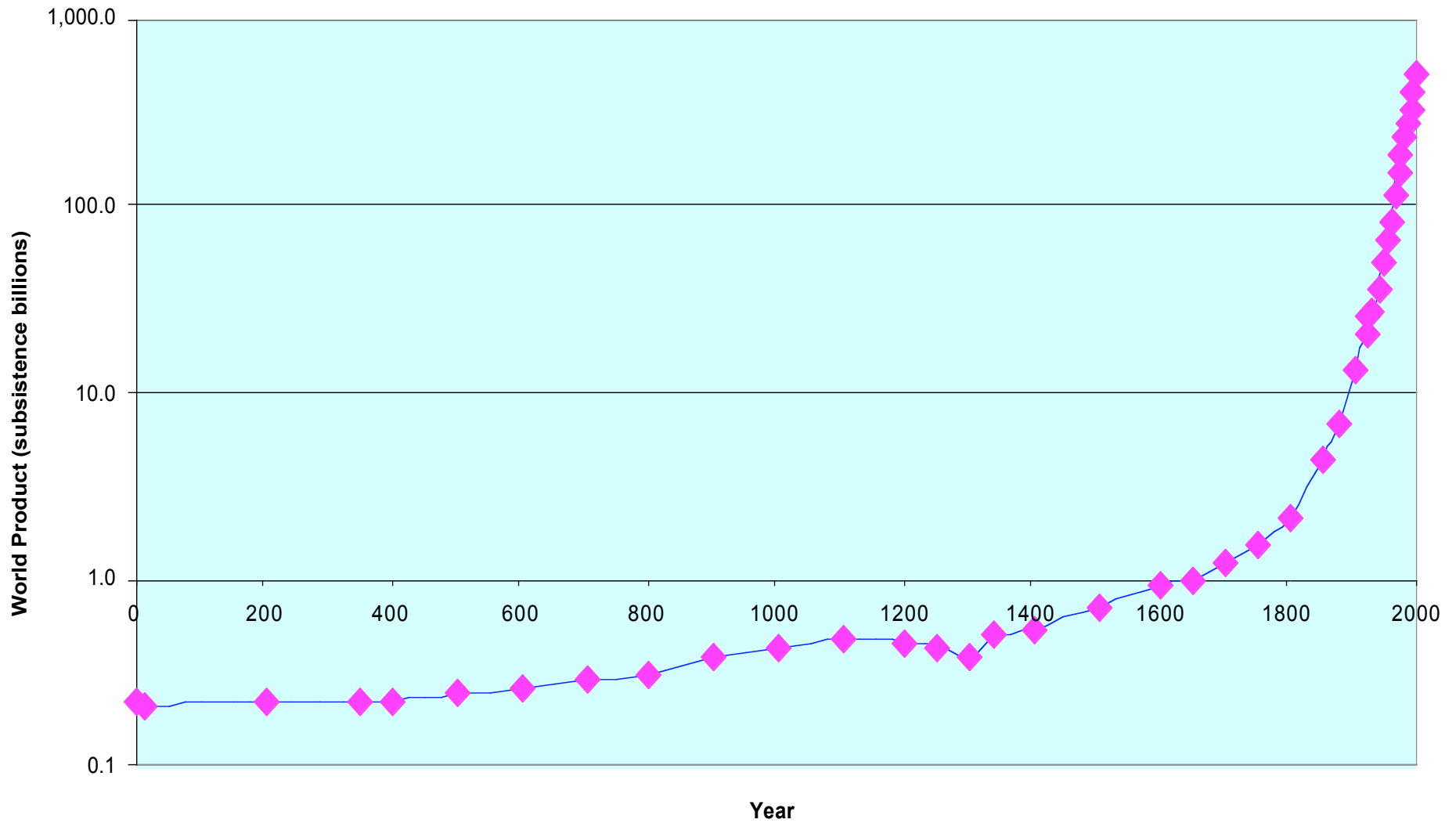
Bigger Brains



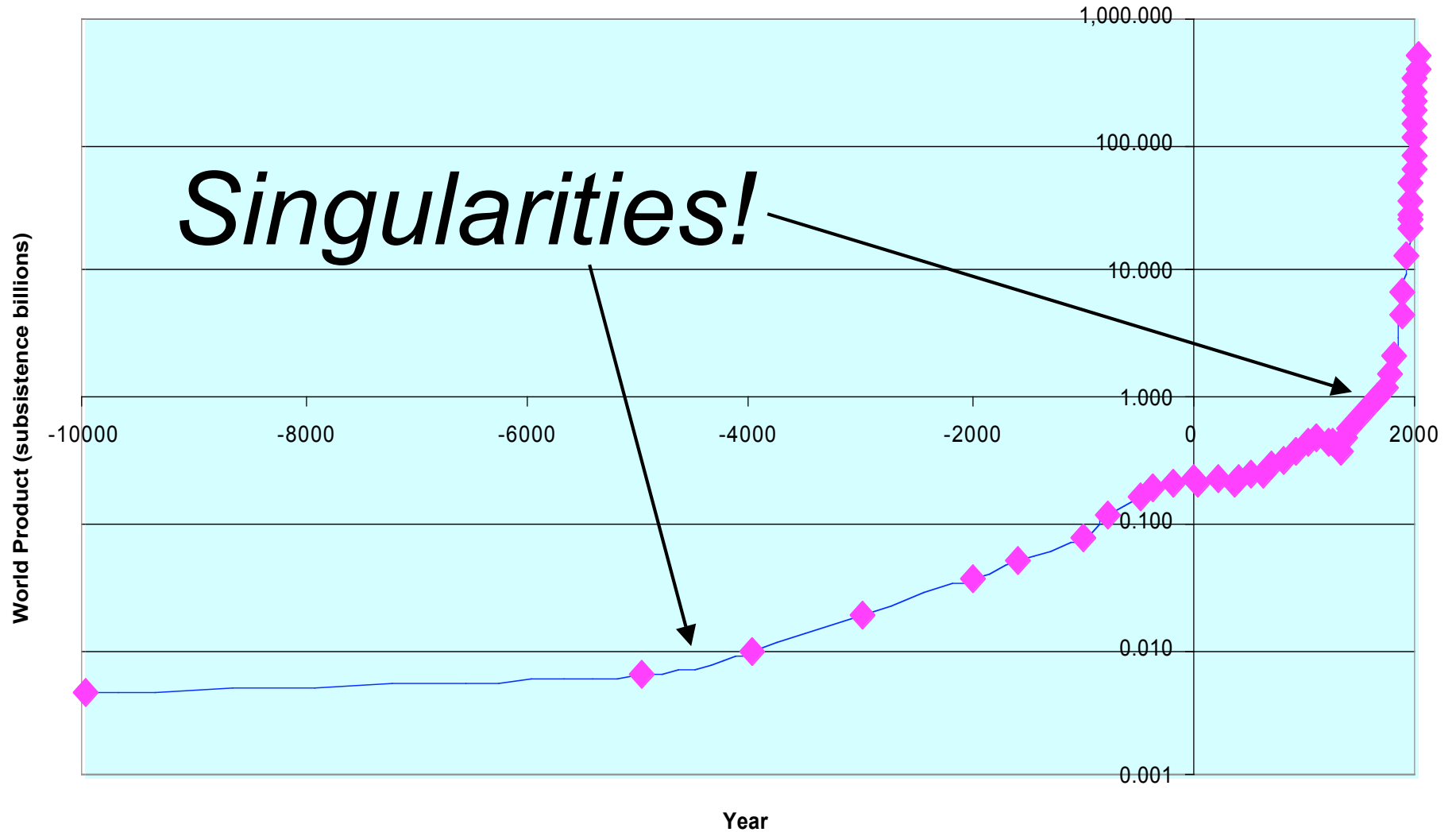
World Product, 1950-2006



World Product, 1-2000



World Product, 10K BC-2K AD



World Product, 2 Million BC+

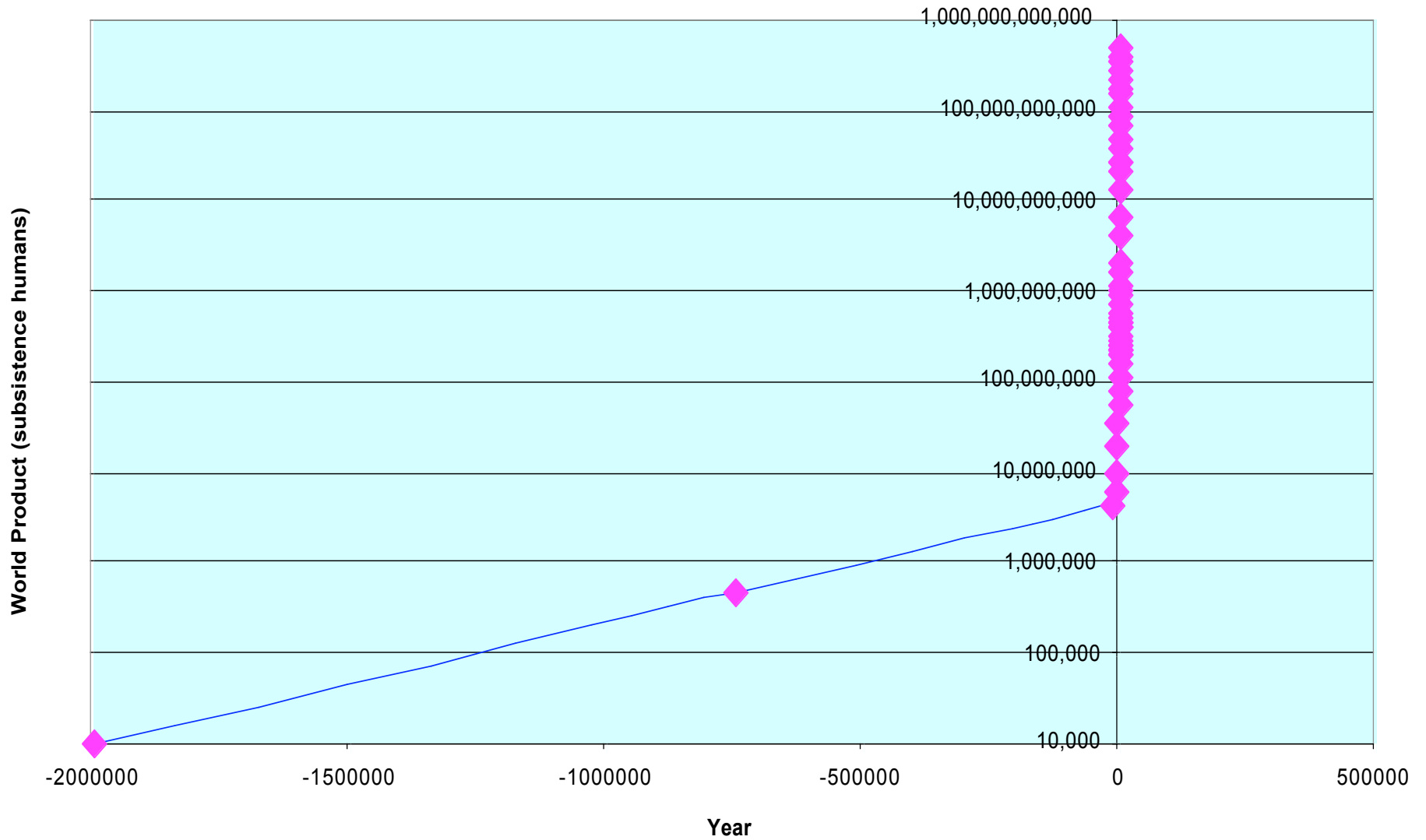
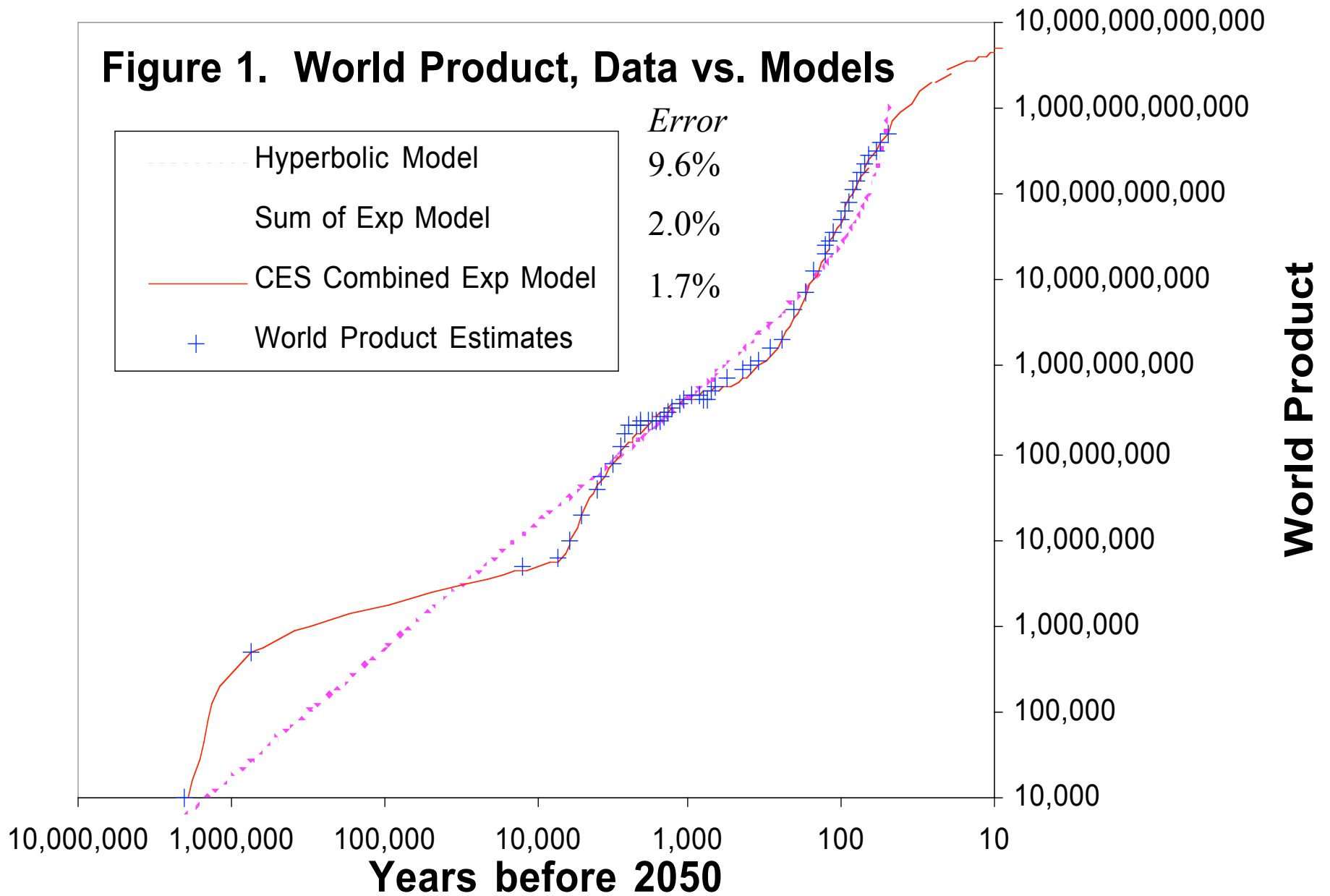


Figure 1. World Product, Data vs. Models



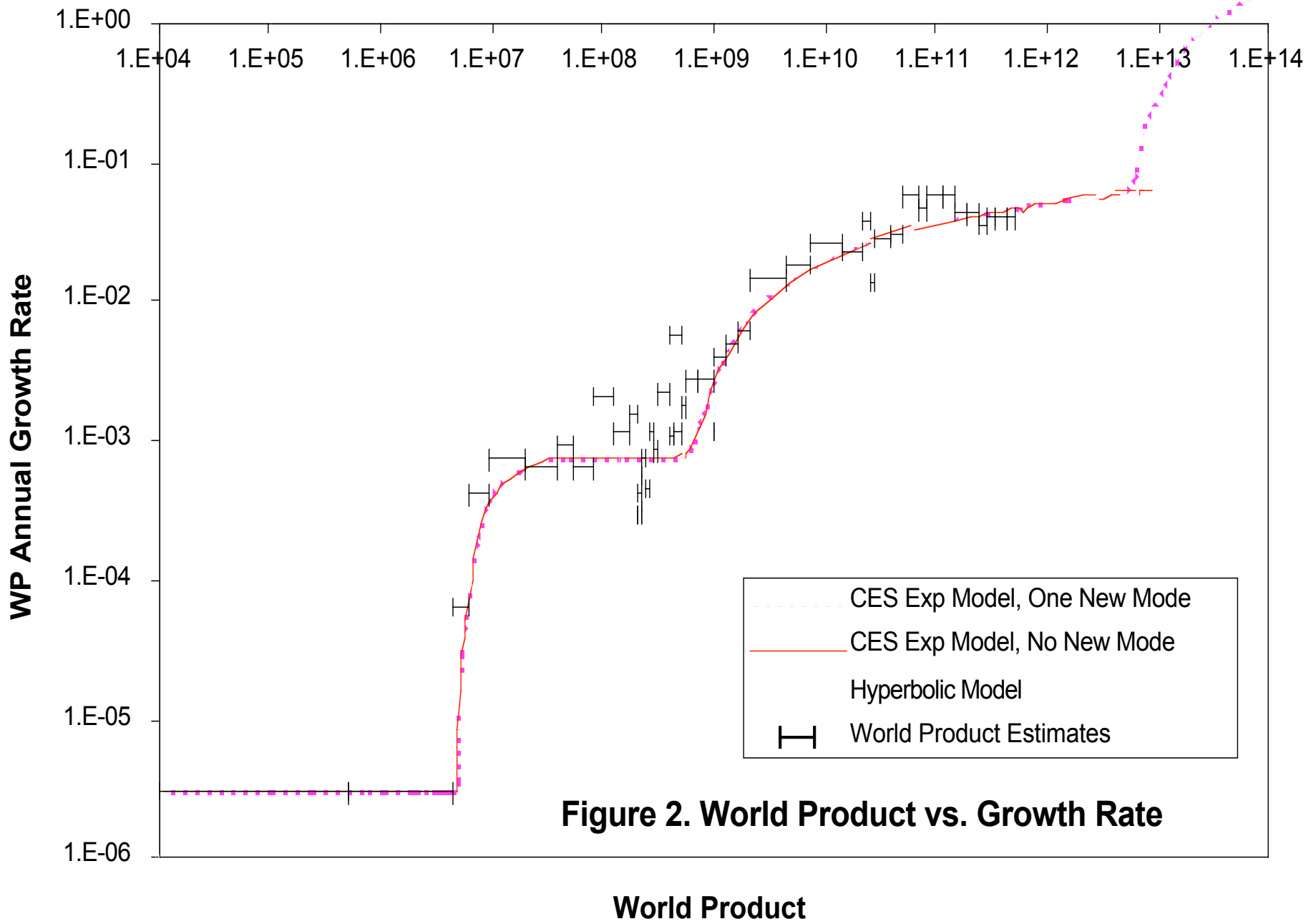
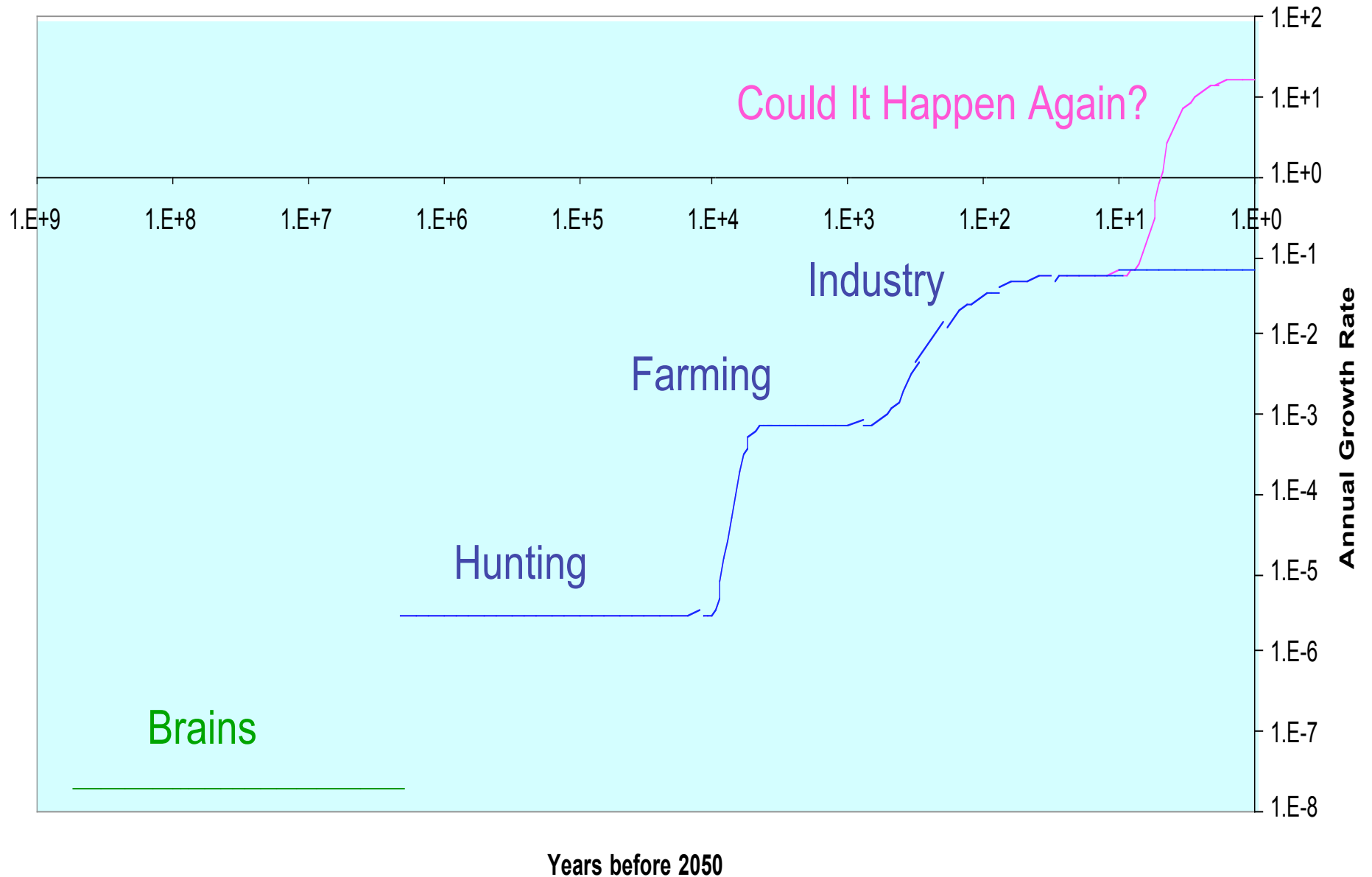


Figure 2. World Product vs. Growth Rate

World Product Growth Rate



Growth Mode Statistics

<i>Growth Mode</i>	<i>Doubling Time</i>	<i>DT Factor</i>	<i>WP Factor</i>
Brains	34 Myr	300?	67,000
Hunting	224 Kyr	153	480
Farming	909 yr	247	190
Industry	6.3 yr	145	>590
?	<2.3 wk?	>145?	?

Forecasting The Next Mode

Growth Mode	DT Factor	Next DT	WP Factor	New Date from WP	New Date from #DT
<i>Brains</i>			"67K"	2072	2120
<i>Hunting</i>	153	2.1wk	480	1996	2075
<i>Farming</i>	247	1.3wk	190	1976	2067
<i>Industry</i>	145	2.3wk	>590		

Sample growth rate transition

Transition date

2039	2040	2041	2042	2043	2044	2045	2046	2047
6.1%	6.1%	6.6%	8.0%	14.0%	40.5%	147.3%	476.2%	1023.2%

First Adopter Gains

<i>New Mode</i>	<i>Initial %</i>	<i>Final %</i>
Brains	<1	20
Humans	5	100
Farming	10	40
Industry	20	50
?	?	?

Why Gains Falling:

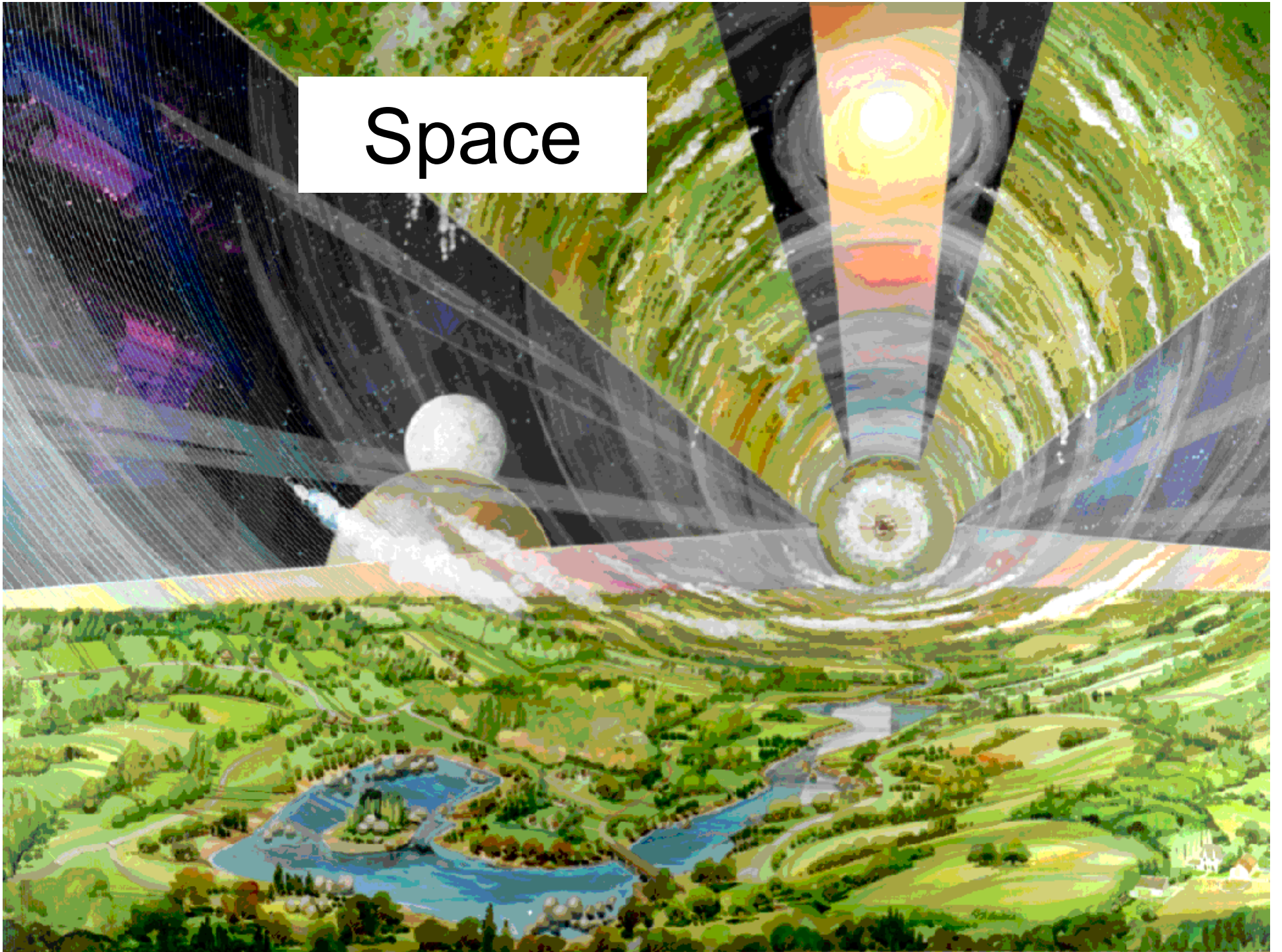
- More ways to copy innovations
- Larger division of labor

Knowledge Was Always Key

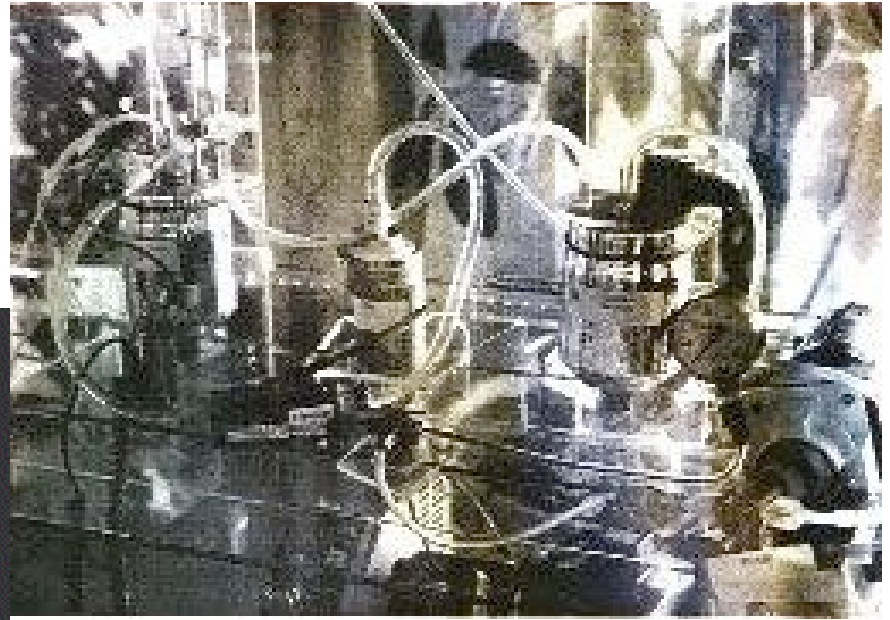
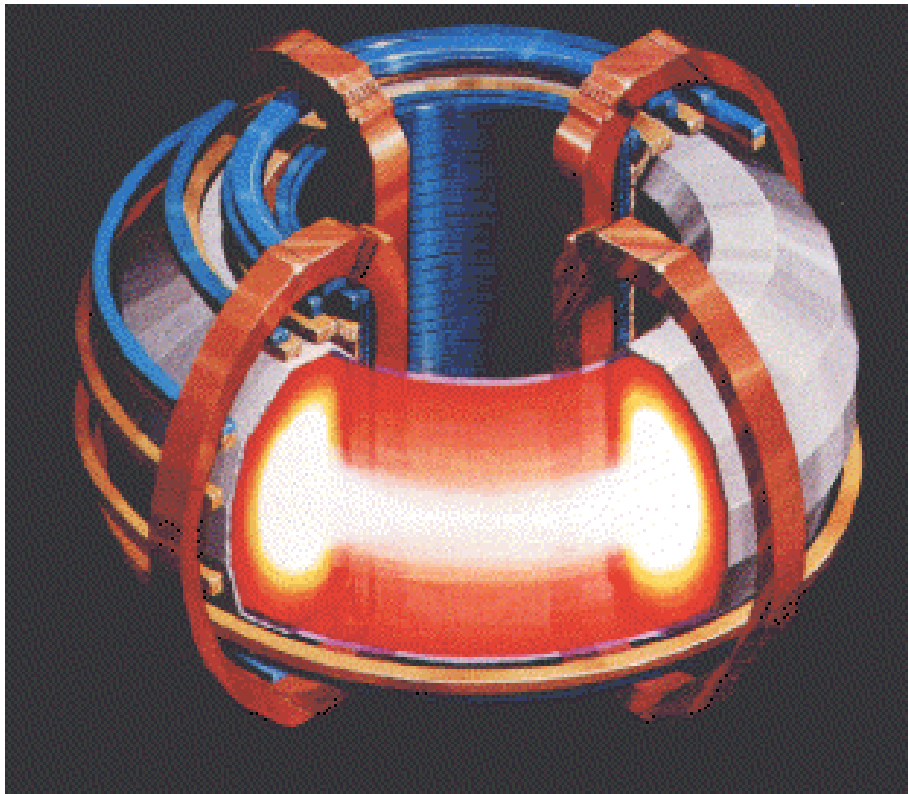
<i>Growth Mode</i>	<i>Encoded</i>	<i>Shared</i>
Brains	DNA	Sex
Hunting	Culture	Watch/Talk
Farming	Culture	Talk/Object
Industry	Writing	Expert Net
?	?	?

What Could Cause
A New Singularity?!

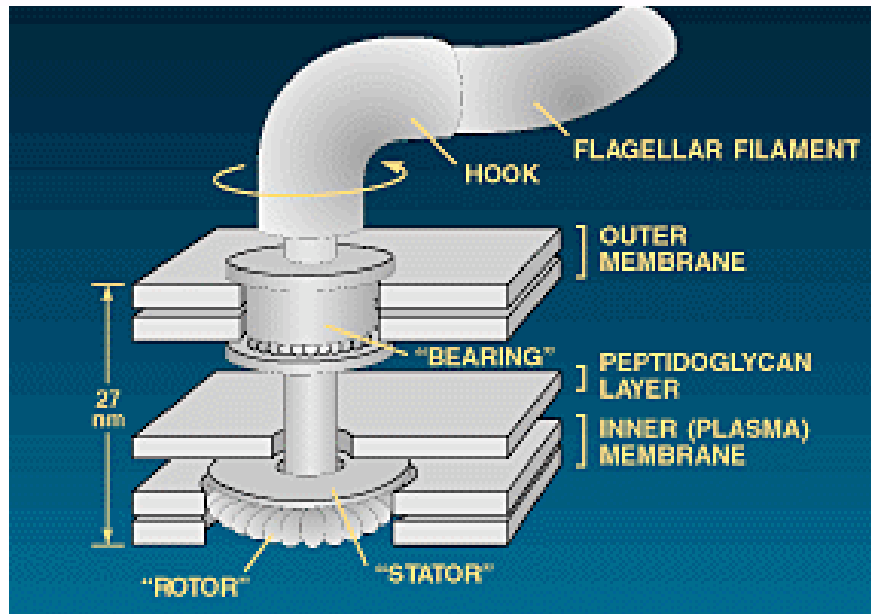
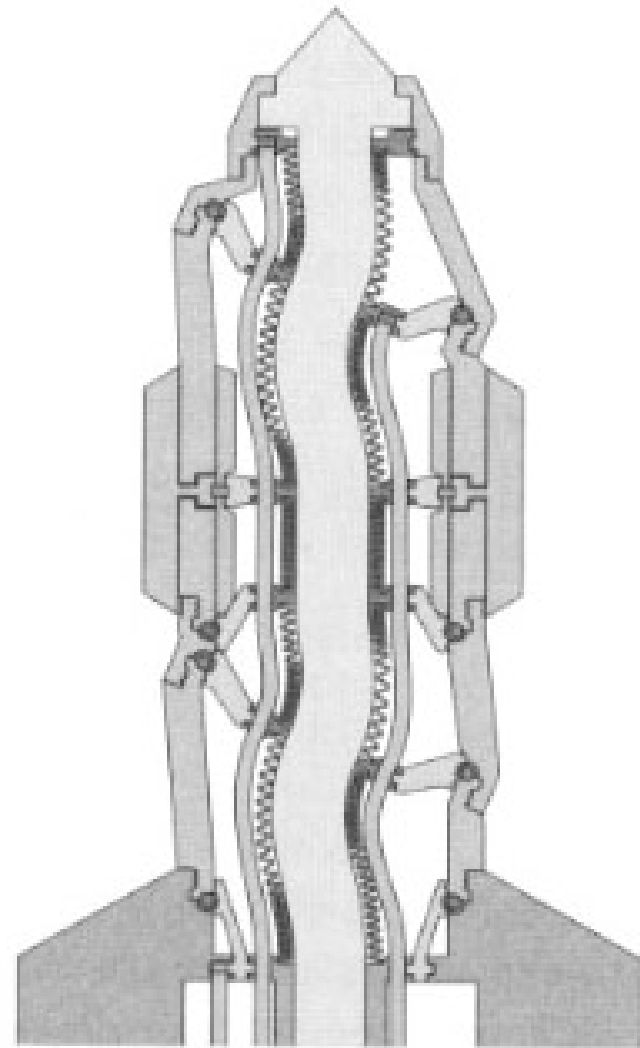
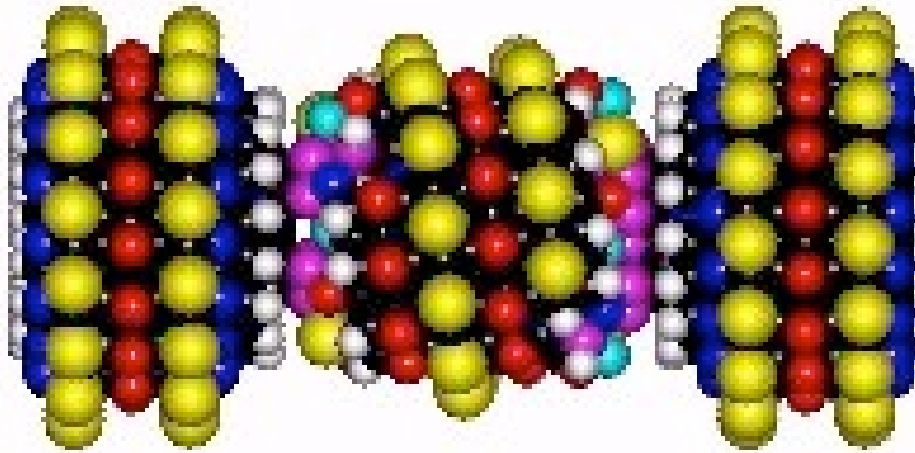
Space



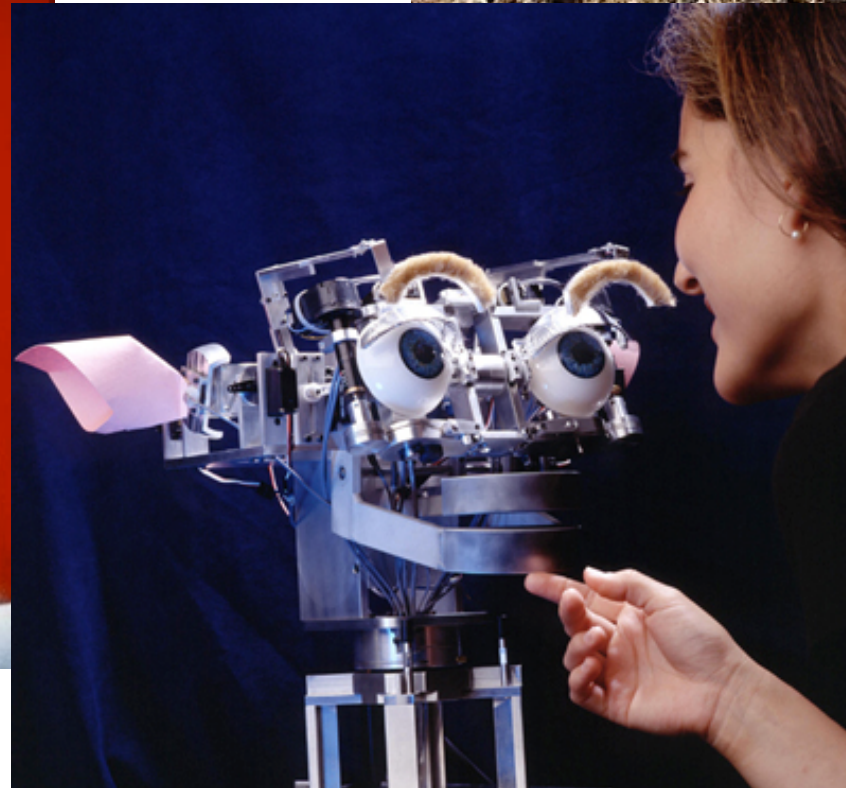
Fusion



Nanotech



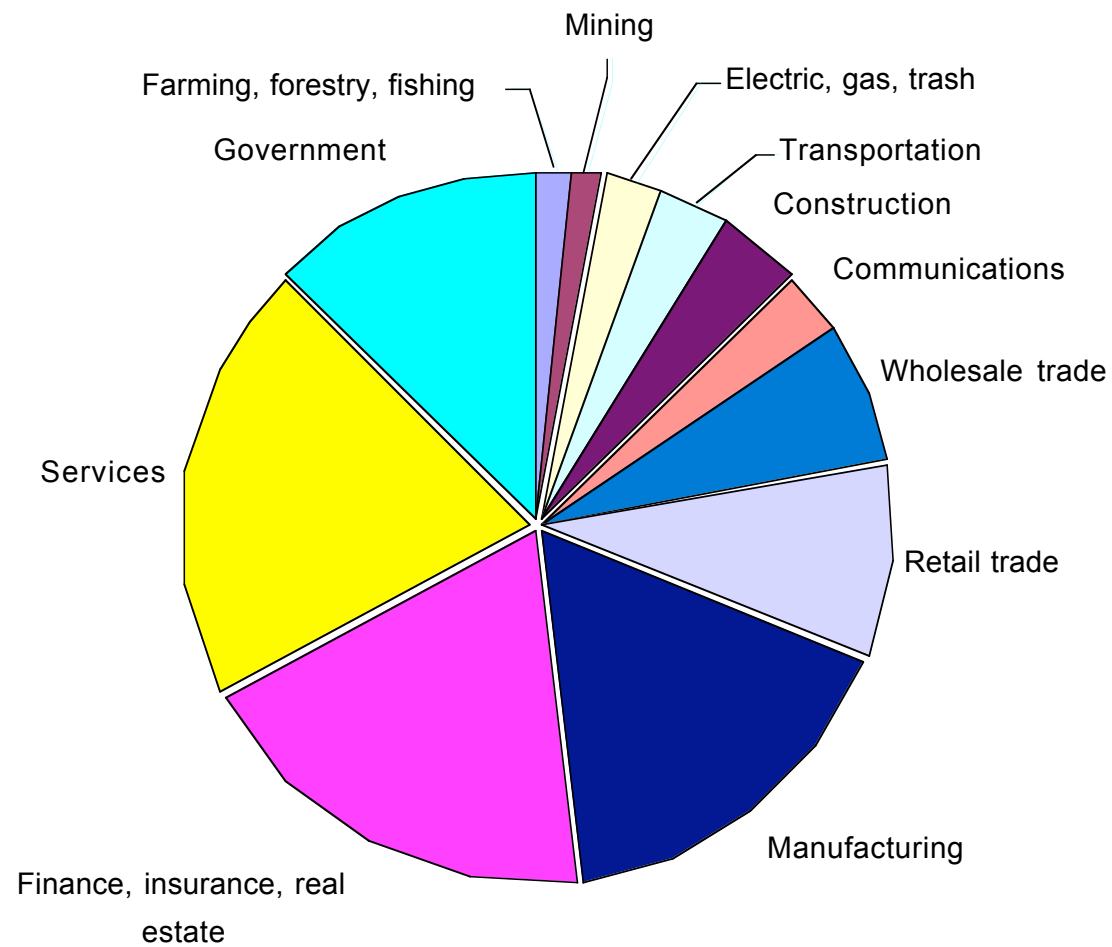
Robots



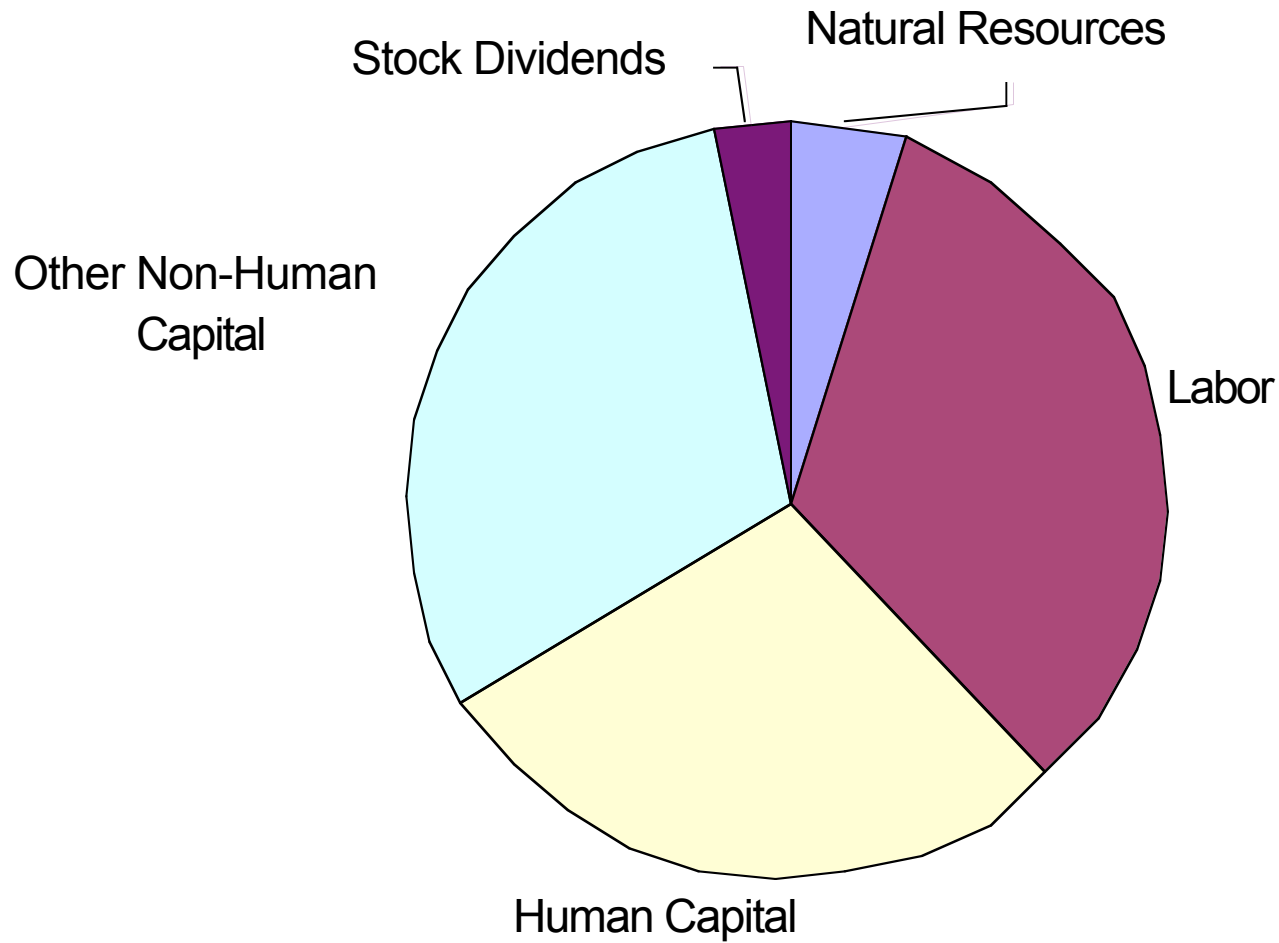
Five Steps to Radical Nanotech

1. Atomic Precision – *put some atoms where want*
Growth can go far; implications of specific products
2. General Plants – *like PCs beat signal processor*
Scale economy to make, easier design, efficient enough
More differentiation, faster evolution of products
3. Local Production – *in homes, highly automated*
Maybe buy lifestyle packages of designs “print” at home
File-sharing, open source, in product designs possible
4. Usually Idle – *fixed » marginal costs, like “info”*
5. Self-Reproduction – *sudden large cost drop?*

Industry Shares of US GDP



Factor Shares of Income



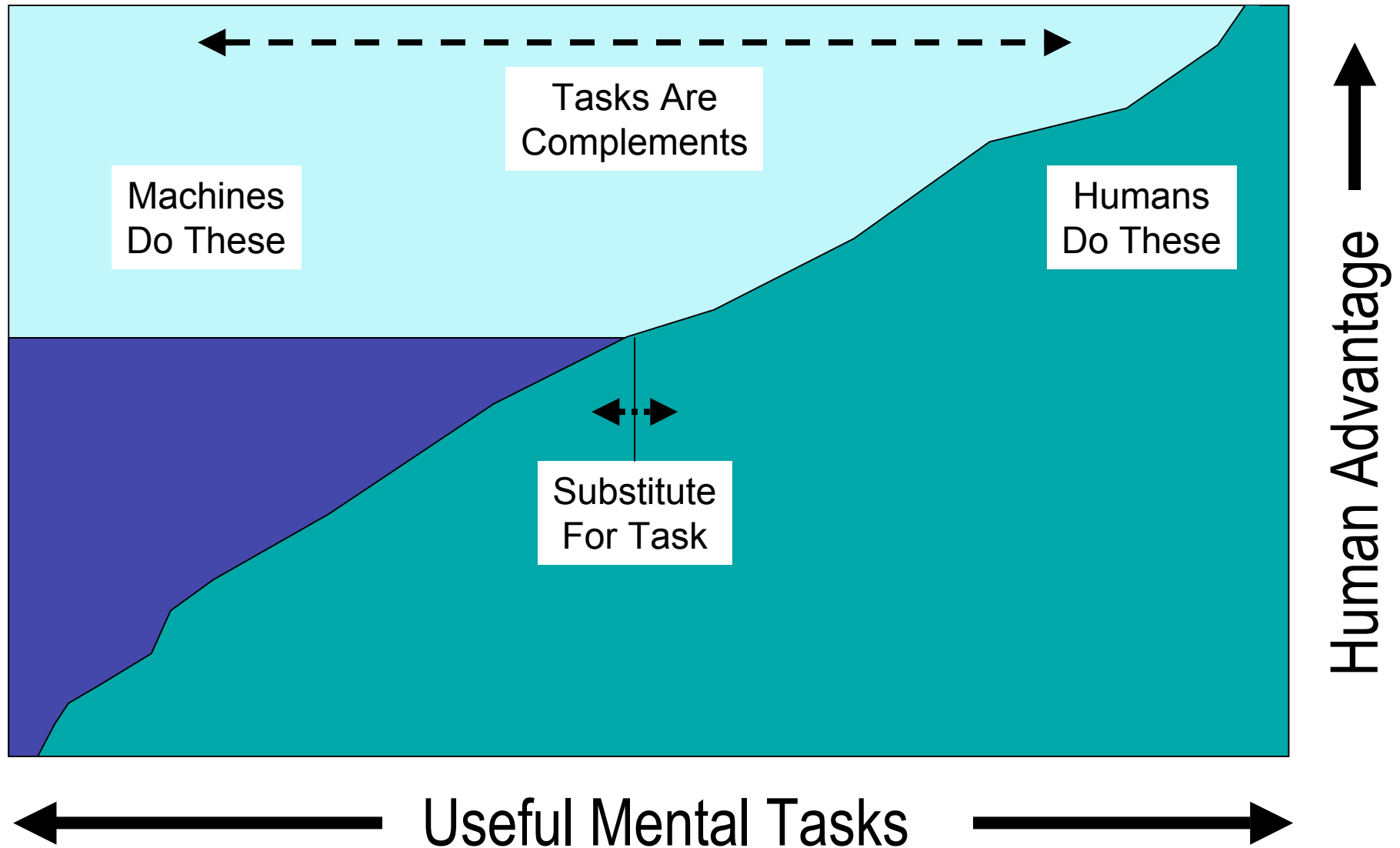
My Views On Singularity

- **Yes:** General machine intelligence *will* come, make *huge* difference
- **Not soon:** roughly 20 to 200 years away
- **Not trend:** econ growth has been steady
- **Not local:** an integrated economy grows together, not basement takes over world
- **Not hand-coded:** probably brain emulation
- **Not horizon:** we *can* see past, if fuzzier
 - _ New economy doubles weekly to monthly
 - _ Natural wages fall below human subsistence
 - _ “Economics of Singularity,” *IEEE Spectrum* 6/08

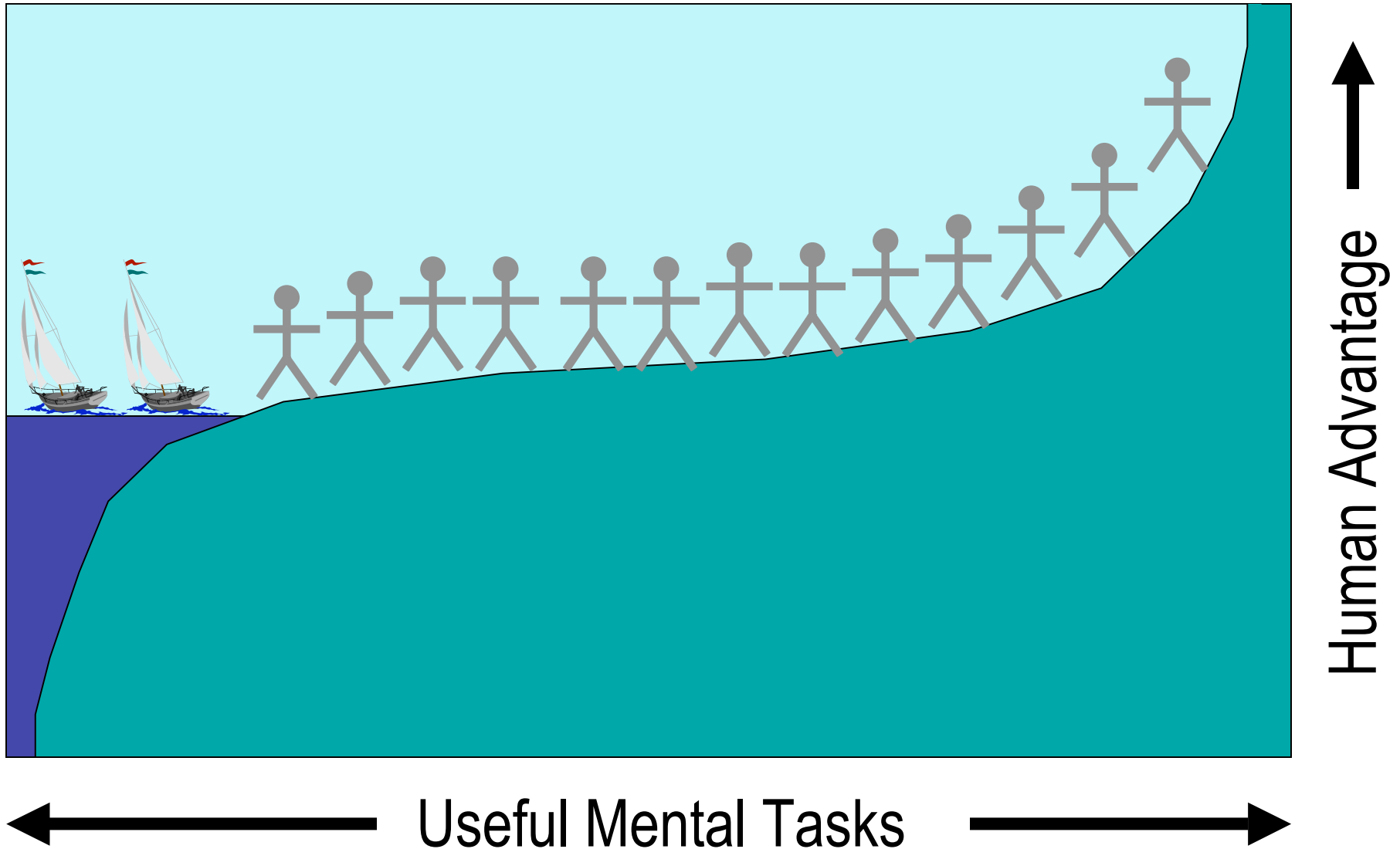
Economics of Robots

- Staple of fiction – ancient legends to TV now
- If have more of X, do you want Y more (complement) or less (substitute)?
- Machine as *Substitute* to human labor
 - Ricardo 1821, most science fiction
 - Wages fall to machine cost
- Automation as *Complement* to human labor
 - Wicksell 1923, modern economics consensus
 - Wages have risen as automation cost have fallen
- So are robots a substitute or complement?

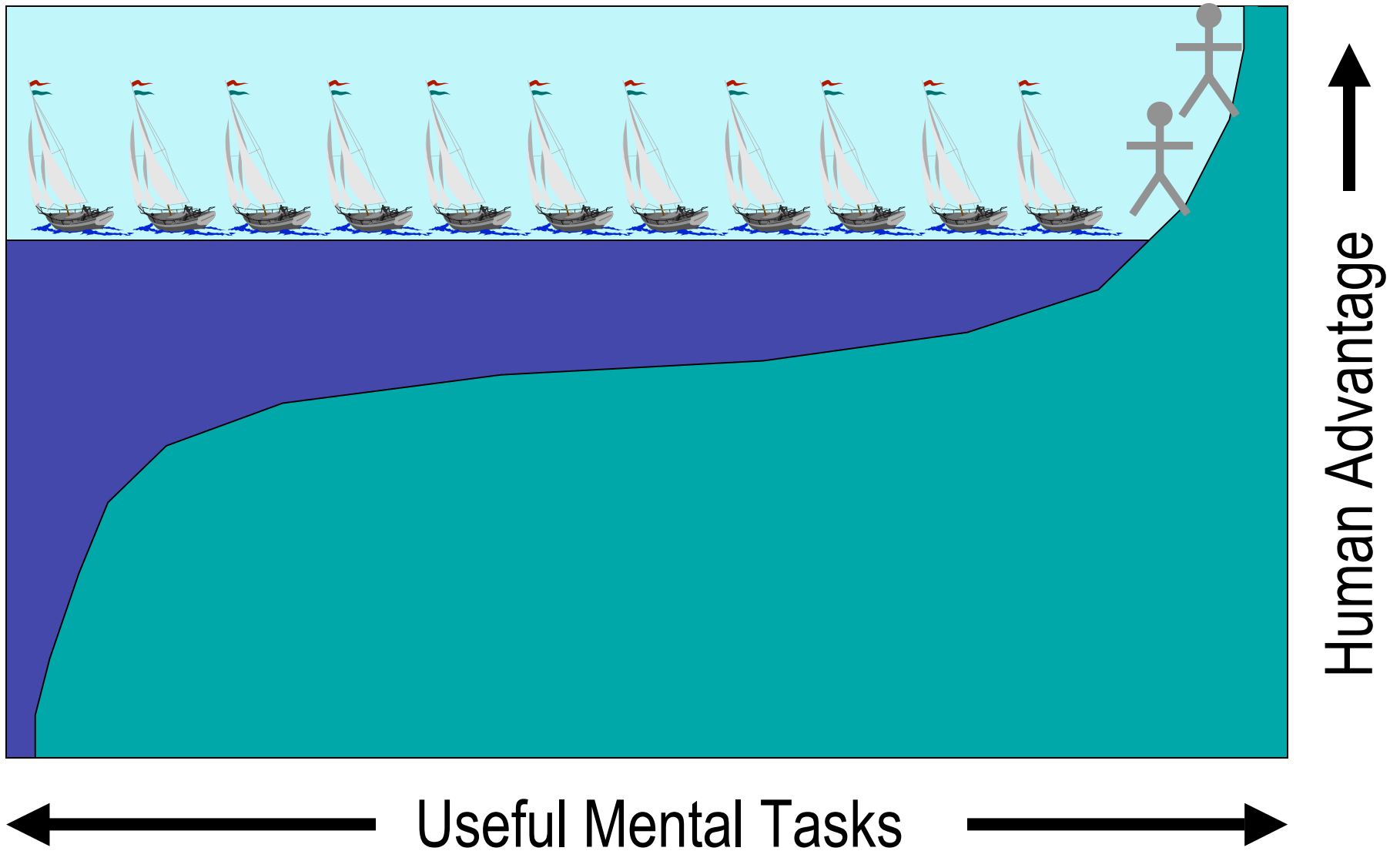
Robots Substitute On Task, But Tasks Are Complements



A Rising Tide



A Rising Tide



A Simple Robot Growth Model

$$Y = A L^\alpha K^\beta M^\gamma \hat{H}^\delta = C + K + P(M + R)$$

$$L = H - \hat{H} + R, \quad Y_K = I, \quad Y_M = (I - g_P)P$$

Assume constant: g_H, g_A, g_P, g_Y, I

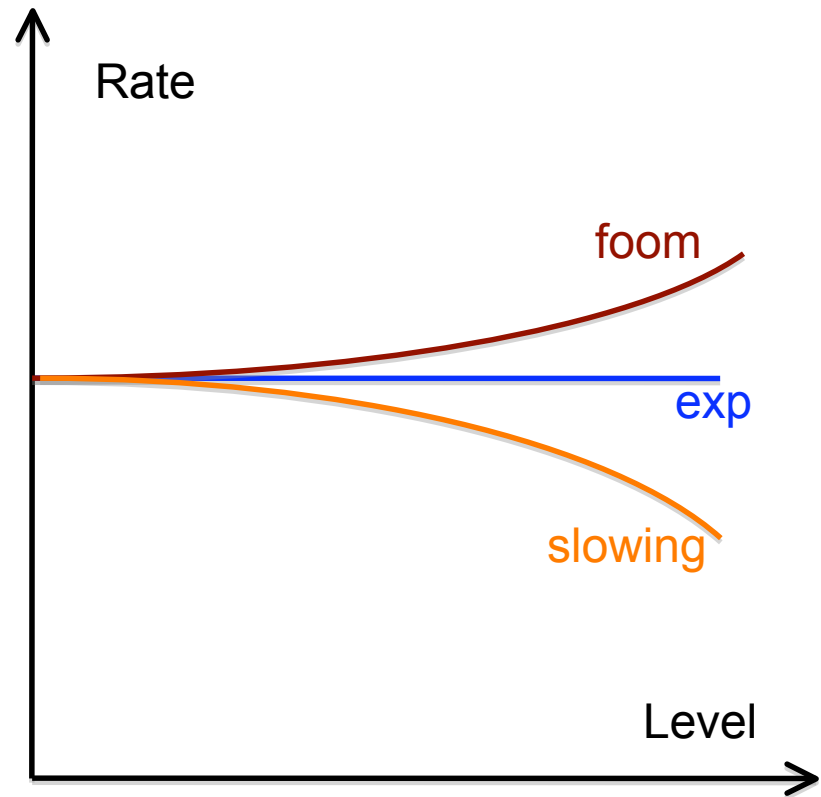
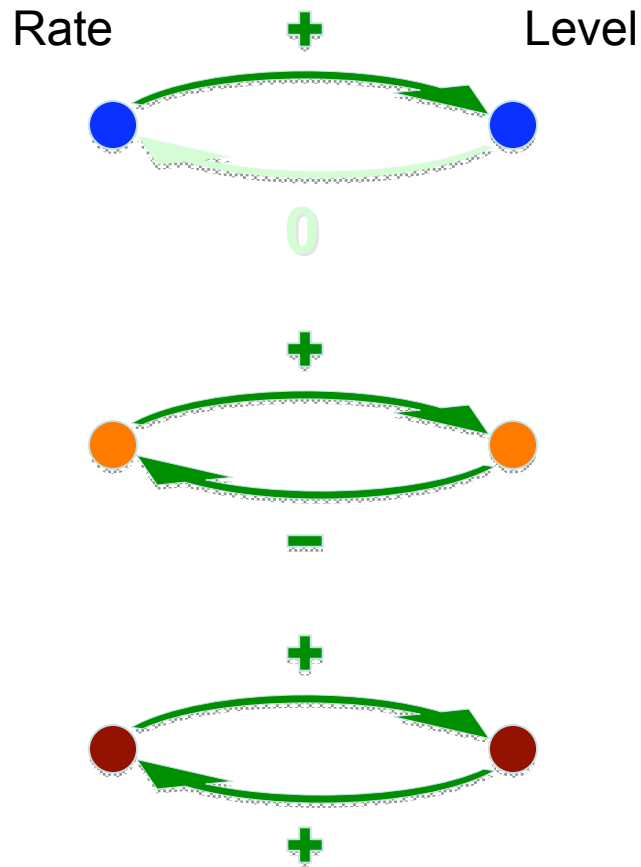
$$(1 - \alpha - \beta - \gamma - \delta) g_Y = g_A - \alpha g_L - \beta g_K - \gamma g_M - \delta g_H$$

$$Y_L < Y_M, \quad R = 0, \quad g_{Y_L} = g_Y - g_H \quad g_Y$$

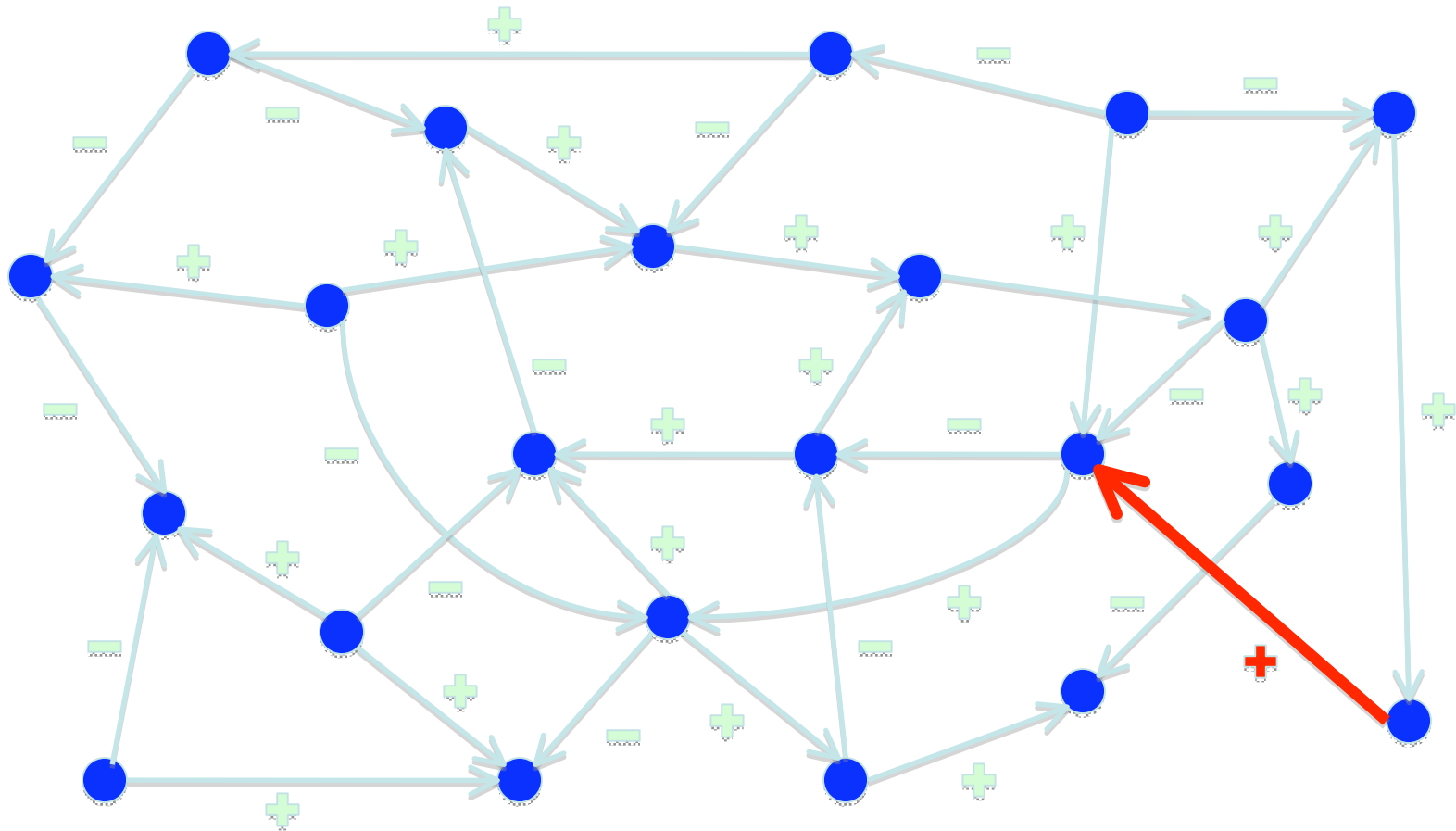
$$Y_L = Y_M, \quad R > 0, \quad g_{Y_L} = g_{Y_M} = g_P \quad \hat{g}_Y$$

Seek These

Simple Growth Models

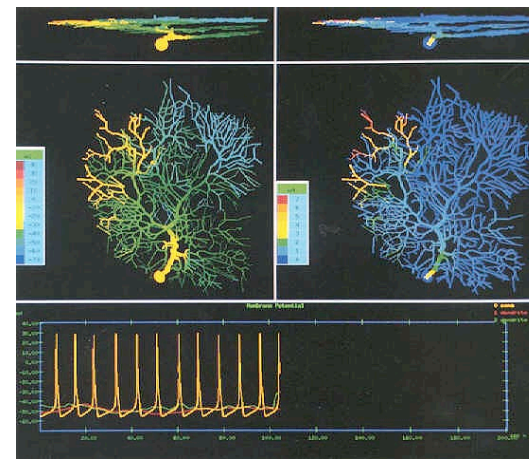
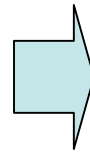
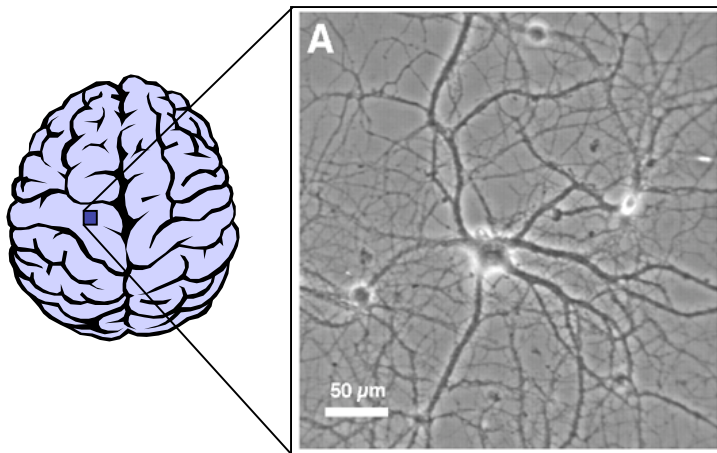
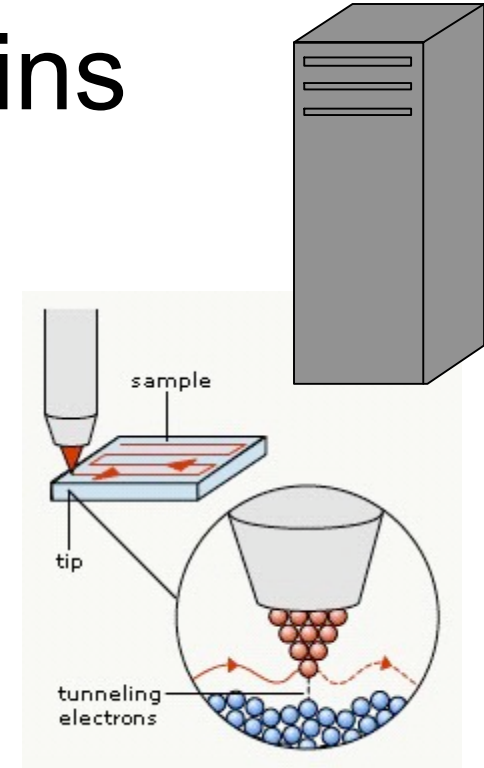


A Complex Growth Model



Needed To Emulate Brains

1. Model each brain cell type
2. Scan – freeze, slice, 2D scan
3. Computer (very parallel task)



Pivotal: What Ready Last?

1. Computing

- Other techs fast or fine brain detail key
- Broad smooth anticipated transition

2. Scanning (least likely?)

- Large coalitions, first dominates; diversify!
- Most in future descend from one human?

3. Modeling

- May be big surprise, so disruptive change

Cheap For Robots

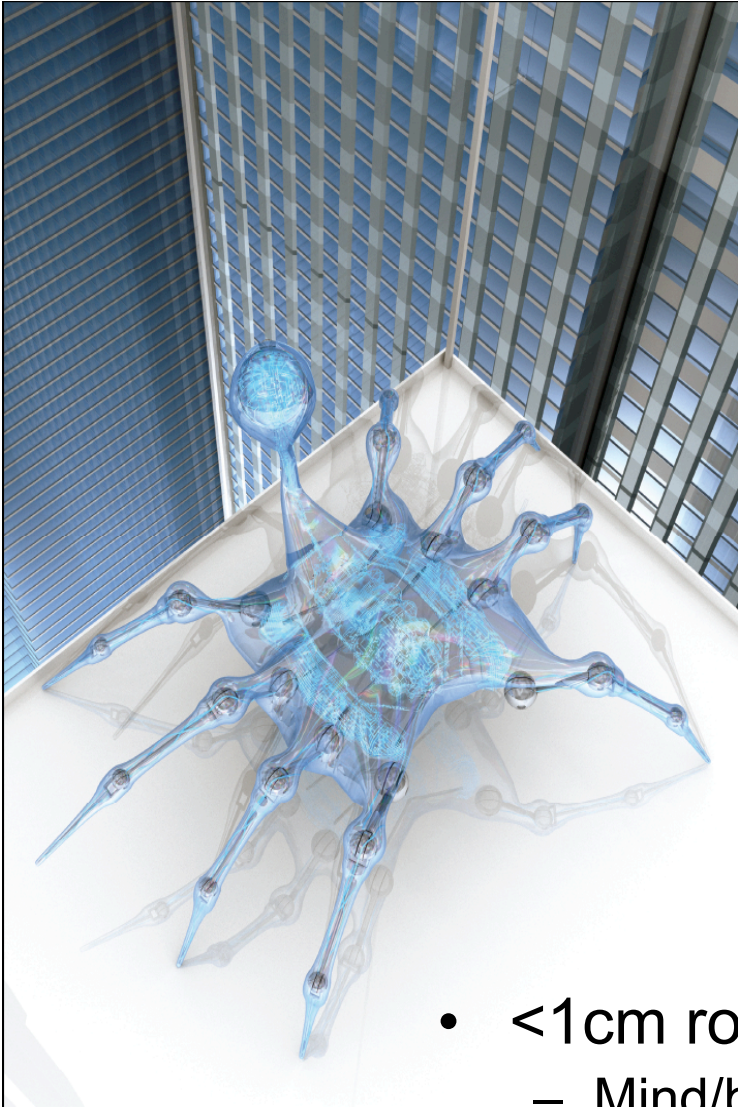
- Immortality (even so, most can't afford)
- Travel – transmit to new body (but security?)
- Nature – don't need ecosystems
- Labor – work less tool intensive
- *Copies!*
 - Malthusian population explosion, rapid growth
 - Wages may fall to fast-falling hardware cost
 - Depends on mental-task landscape shape
 - Happens if they slave or if free
 - Only Draconian population/wage laws could stop

Emulations Feel Human

- They remember a human life
- Retain human tendencies
 - love, gossip, argue, sing, violate, play, work, innovate
- More alienated worlds - as were farms, factories
 - Office work in virtual reality
 - Physical work in android bodies
- More unequal abilities, like our fantasy
 - Can run minds faster, use wildly different bodies
- Many won't believe are conscious, or "is me"
 - But same social implications, few dozen is plenty

Humans Eclipsed

- Wages well below human subsistence
 - Some humans may find servant jobs
- But rich *if* held non-wage assets
 - Investments double as fast as economy!
- Robot-Human war unlikely if integrated
 - E.g., left-handed don't war against righties
- Most emulations of the few best humans
 - First mover advantage to show quality



More Implications

- Copies rent bodies, or own on loan
 - Evicted if can't pay!!
- To recoup training investment, copy cabal limits copy wage
 - Security to prevent bootleg copies!
- Fast growth discourages transport, encourages local production
- Laws hold copies co-responsible
- <1cm robots seem feasible
 - Mind/body sped up with size reduction
 - 0.2in. tall => Subjective year/day in 24hr/4min
- One skyscraper holds billions - is megacity
 - City radius now is hour travel distance => 10sec