



## Seminar 2: Exponentials, Flows, and Lags

- Recap from last seminar
- Exponential Curves
- Stock & Flow Diagrams
- Effect of Information Delays



## Last Seminar...

- | → Concepts                                  | → Exercises     |
|---|-----------------|
| ↳ Definition of a system                    | ↳ Sleep Words   |
| ↳ Wholes vs. Parts                          | ↳ Pole Lowering |
| ↳ System Interactions                       | ↳ Living Loops  |
| ↳ Emergent Properties                       |                 |
| ↳ Reinforcing & Balancing<br>Feedback Loops |                 |
| ↳ Limits to Growth                          |                 |

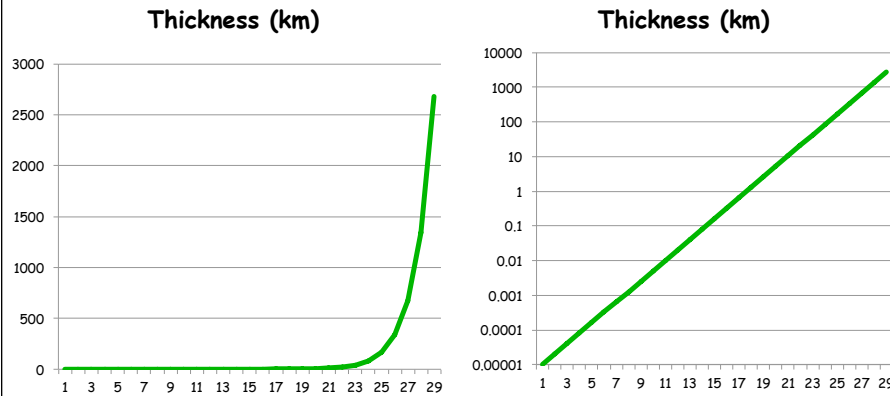




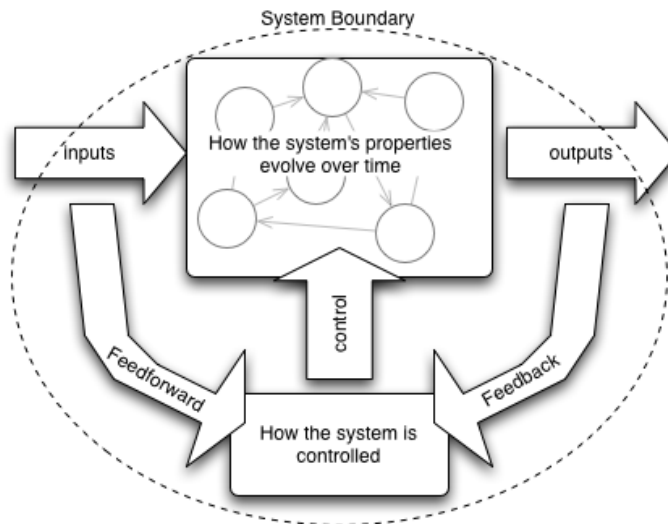
# Paper Folding

→ After 4 folds, 1 cm thick

→ How thick after 29 more folds?

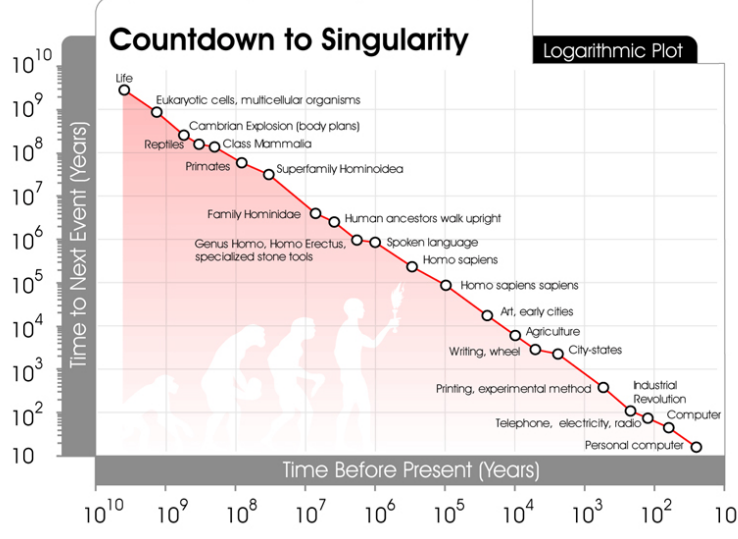


# What does a system need for growth?





# Kurzweil's Singularity?

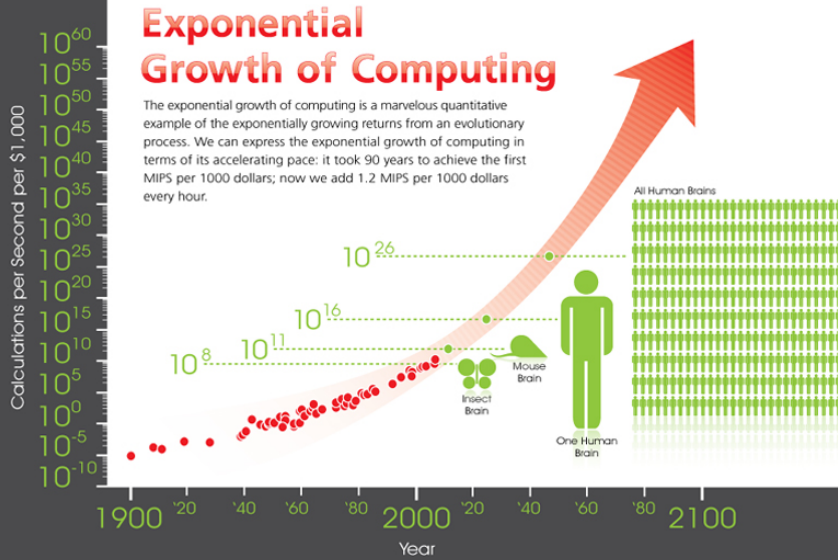


© 2012 Steve Easterbrook. This presentation is available free for non-commercial use with attribution under a creative commons license.



# Exponential Growth of Computing

The exponential growth of computing is a marvelous quantitative example of the exponentially growing returns from an evolutionary process. We can express the exponential growth of computing in terms of its accelerating pace: it took 90 years to achieve the first MIPS per 1000 dollars; now we add 1.2 MIPS per 1000 dollars every hour.

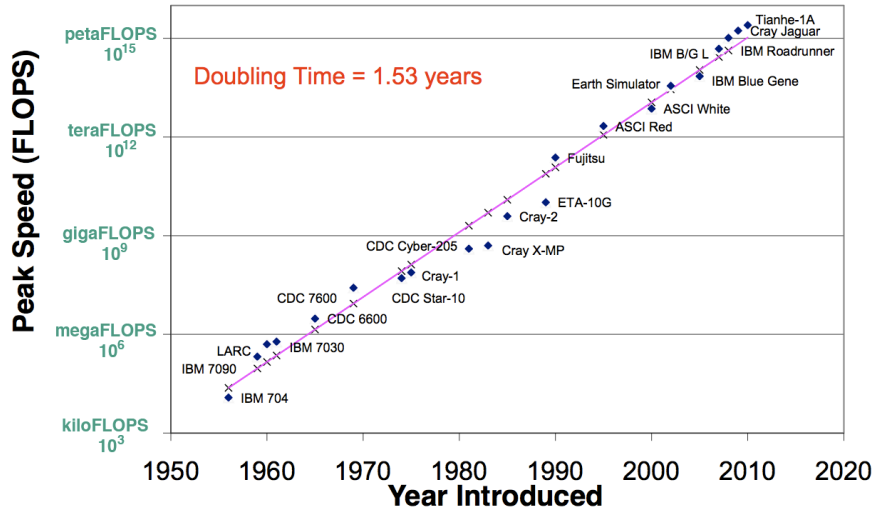


Source: Ray Kurzweil and KurzweilAI.net

© 2012 Steve Easterbrook. This presentation is available free for non-commercial use with attribution under a creative commons license.



# Moore's Law

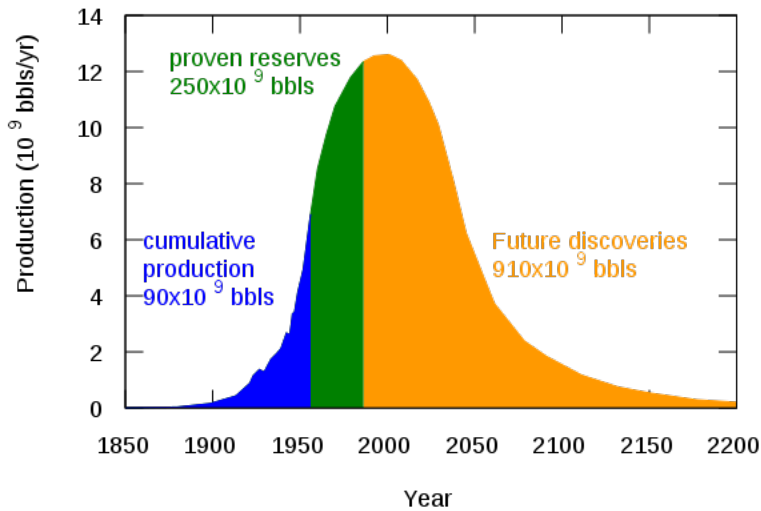


© 2012 Steve Easterbrook. This presentation is available free for non-commercial use with attribution under a creative commons license.

7



# Hubbert's Peak (theory)

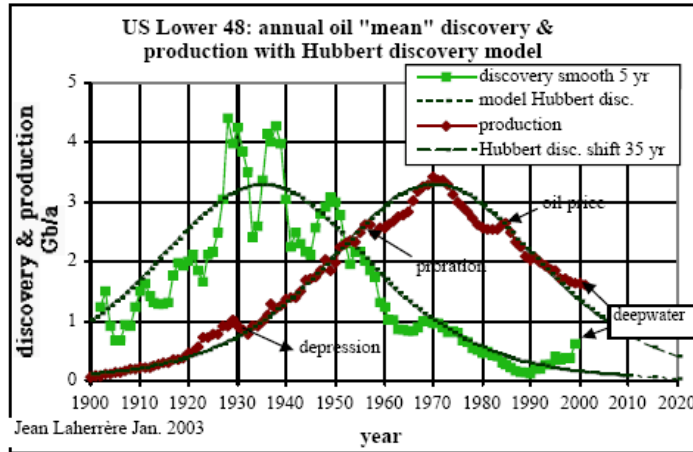


© 2012 Steve Easterbrook. This presentation is available free for non-commercial use with attribution under a creative commons license.

8

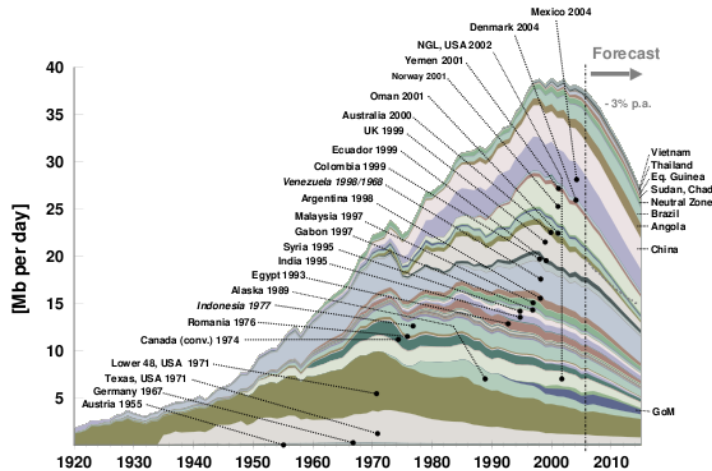


# Hubbert's Peak in the US



# Hubbert's Peak

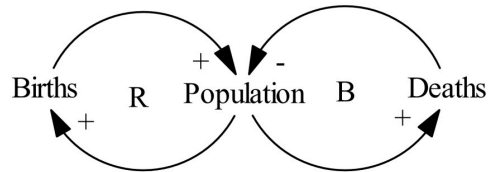
Figure 5: Oil producing countries past peak



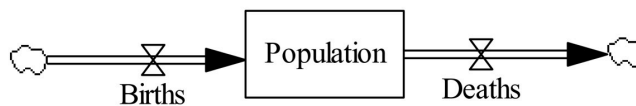


# Stocks and Flows Diagrams

(a)



(b)



# Example Stock'n'Flow Diagrams

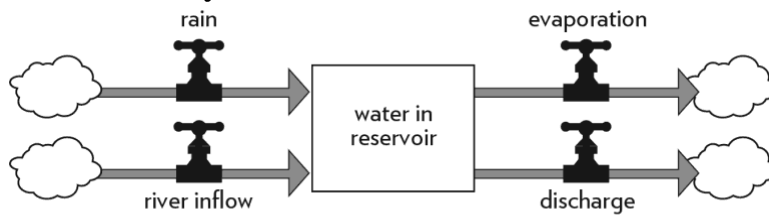


Figure 3. A stock of water in a reservoir with multiple inflows and outflows.

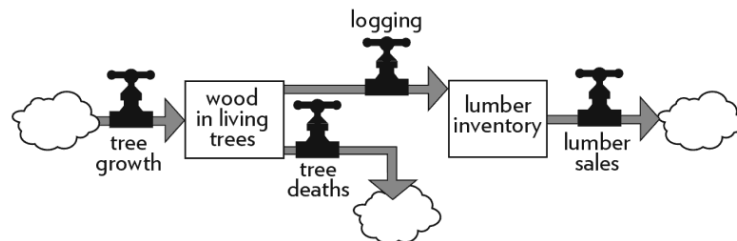


Figure 4. A stock of lumber linked to a stock of trees in a forest.





### With Feedback Loops

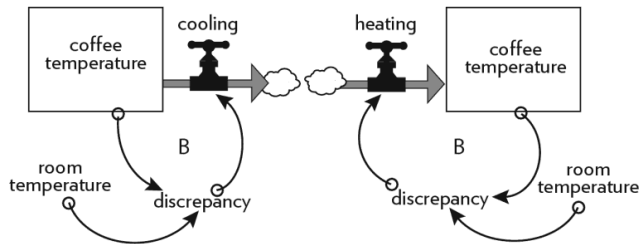


Figure 10. A cup of coffee cooling (left) or warming (right).

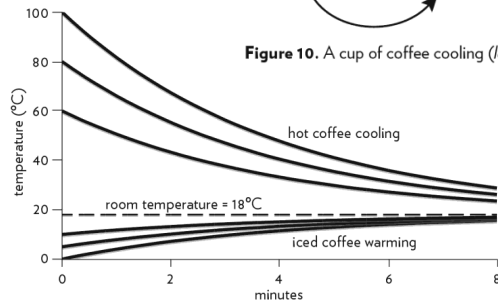


Figure 11. Coffee temperature as it approaches a room temperature of 18° C.



### House Thermostat

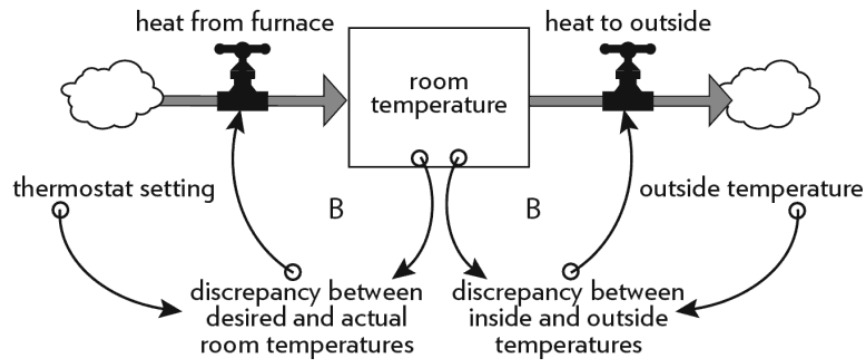


Figure 15. Room temperature regulated by a thermostat and furnace.



## But the room doesn't stay warm!

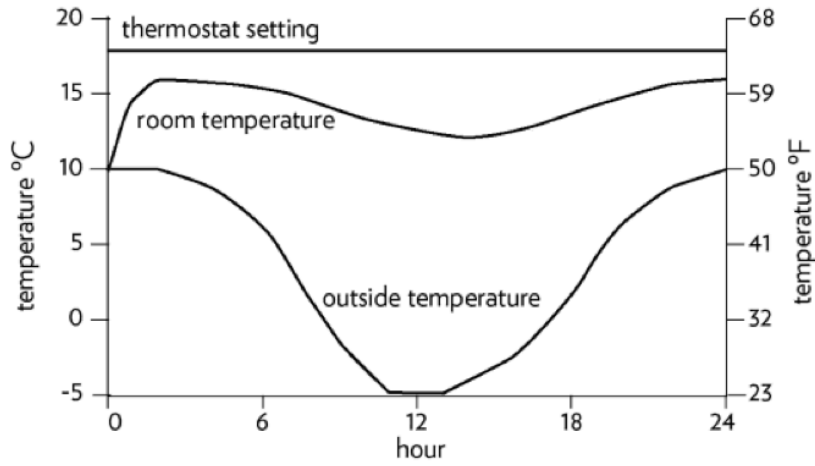


Figure 20. On a cold day, the furnace can't keep the room warm in this leaky house!



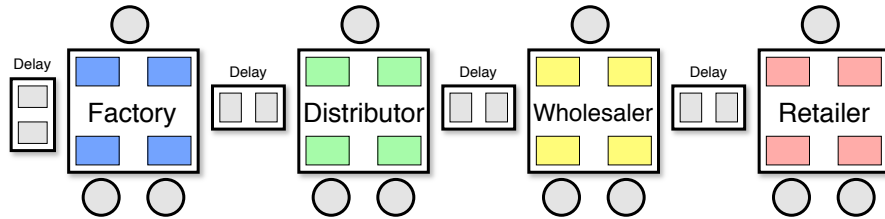
## Information Lags



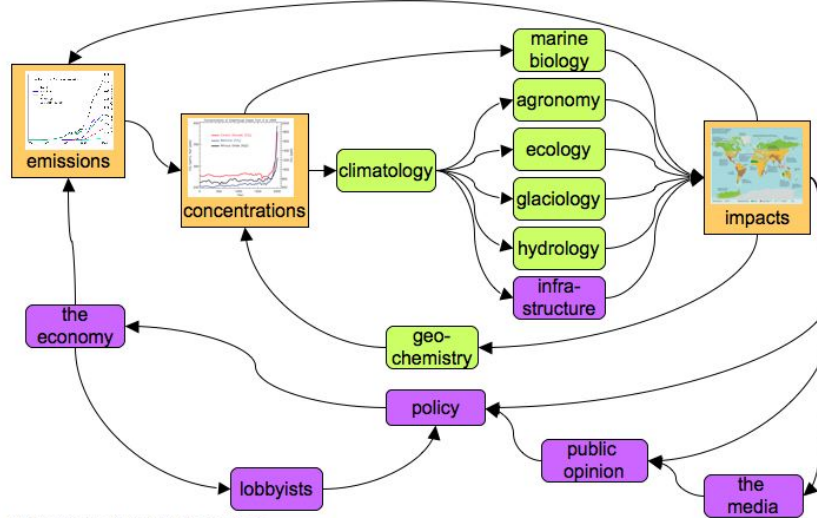




# The Beer Game



# Information Lags in Climate Change



Adapted from a diagram by Michael Tobis