

# ***The Replicating Rapid-prototyper***

*moving hardware through the wires*

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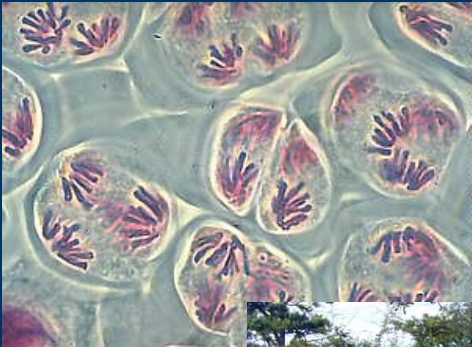
**University of Bath**

**Reflections | Projections 2006 - University of Illinois**

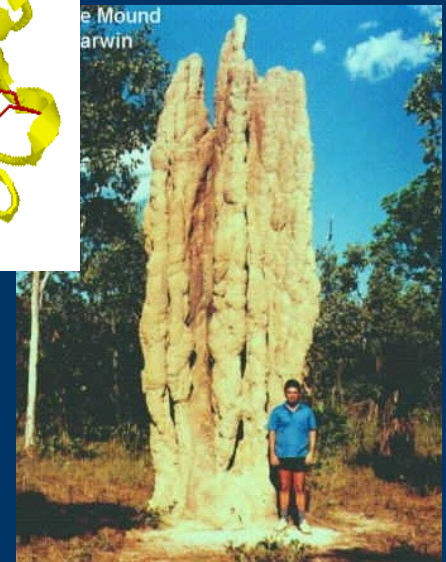
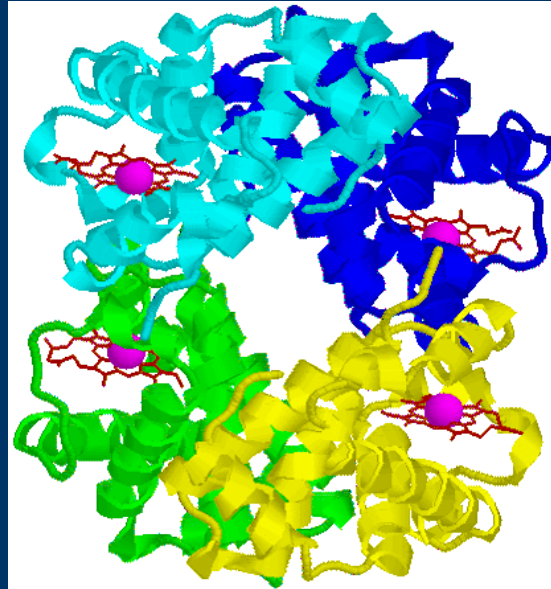
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# *The two most important phenomena in biology*

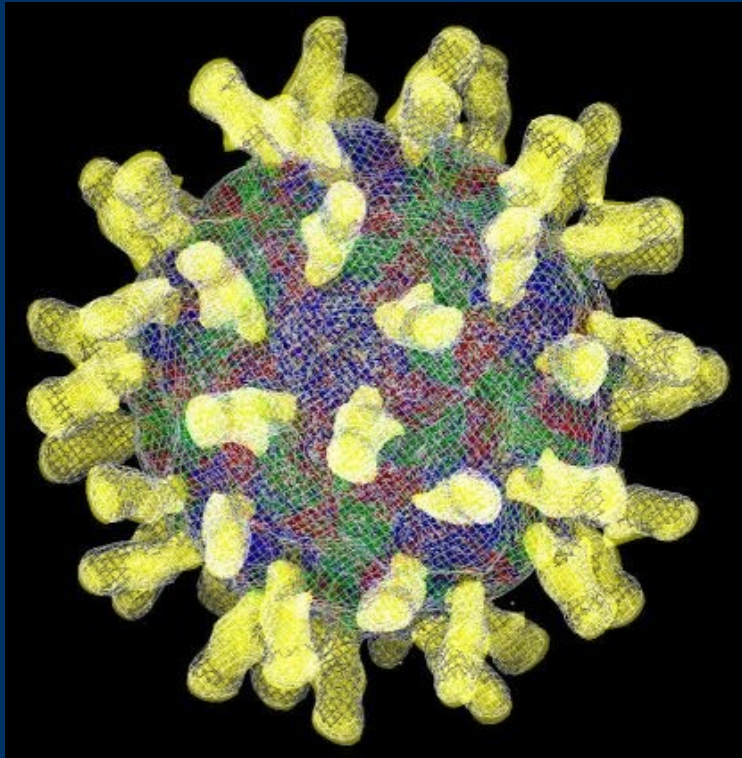


Self Replication



Self Assembly

*Simple replicators get complicated  
replicators to do the assembly.*



Rhinovirus



H. sapiens

# *Symbiosis*



nectar <-> reproduction

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# *Symbiosis*



nectar <-> reproduction

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# *Symbiosis*



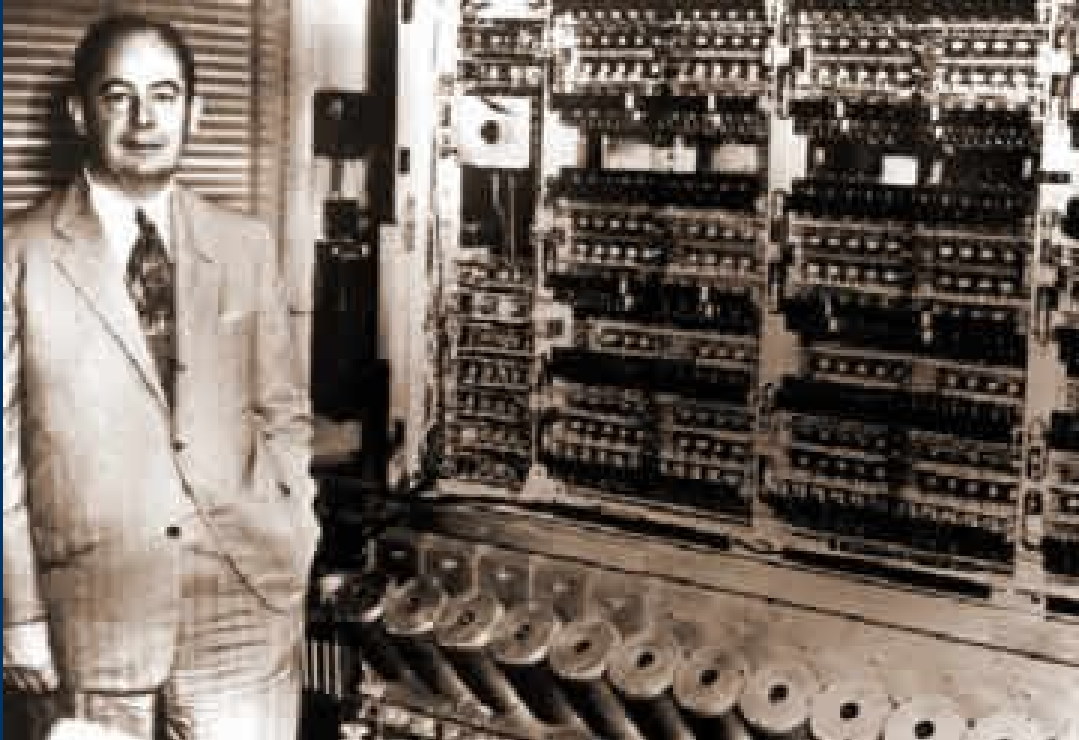
nectar <=> reproduction



cookies <=> reproduction



# *Artificial self replicators & assemblers*



John von Neumann with ENIAC

**John von Neumann:**

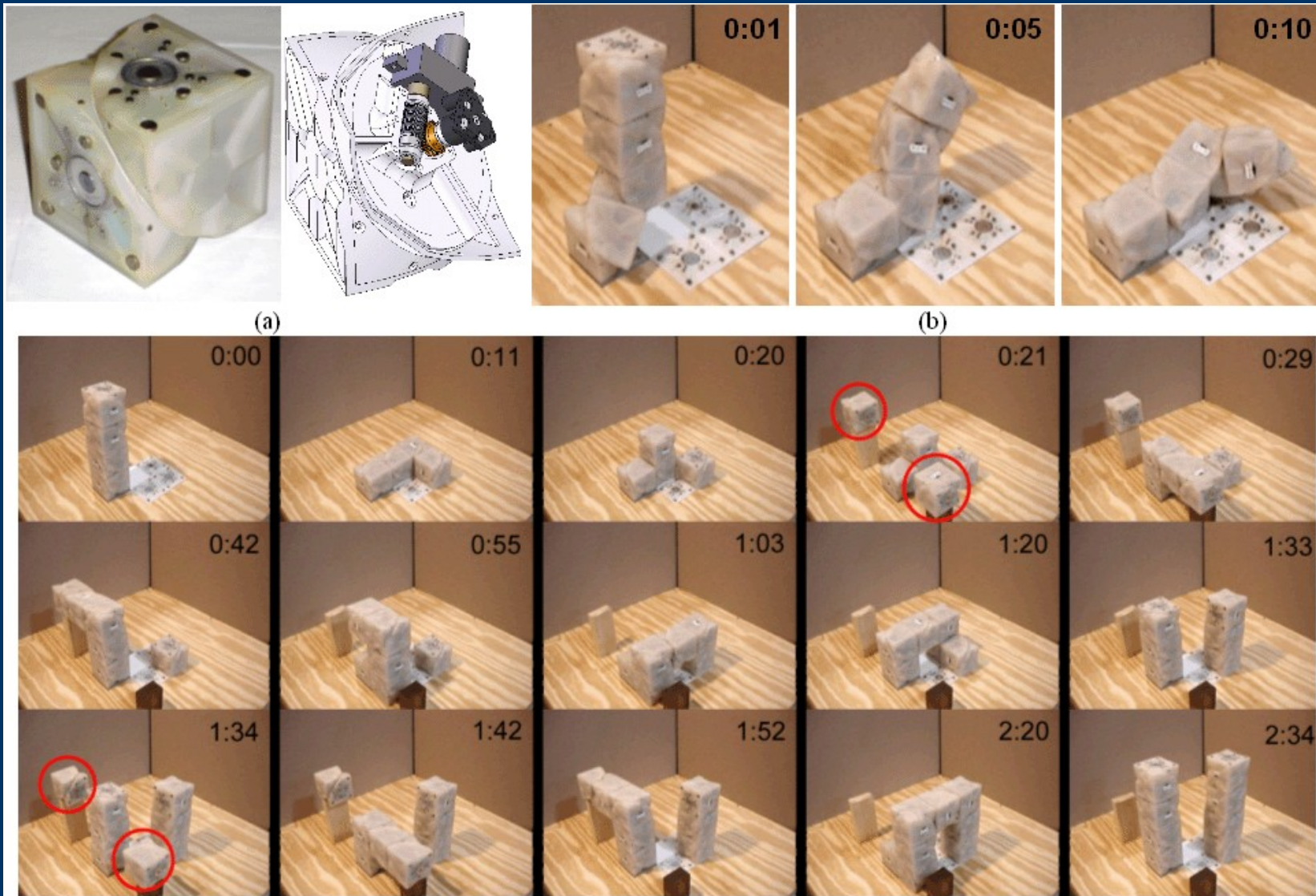
*Universal Constructor*  
(1950s)

A Universal Constructor would be a computer linked to a manufacturing robot.

**The combination would be able to copy themselves.**



# Artificial self replicators & assemblers



Viktor Zykov, Hod Lipson *et al.* (2005)



# *Suppose we made a machine that:*

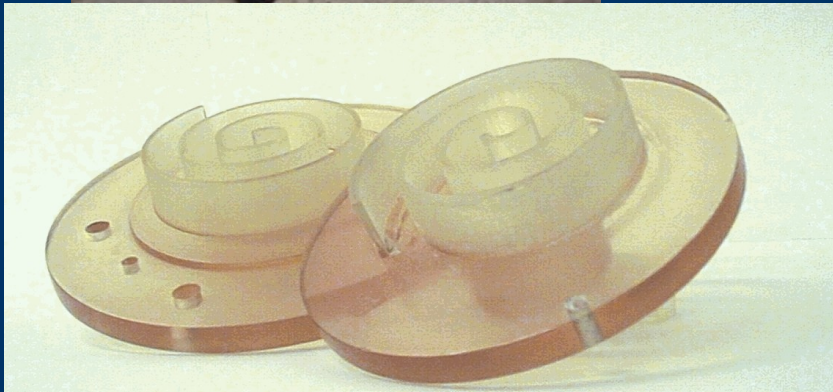
- Self-replicated, but didn't self-assemble (like a virus)
- Existed symbiotically with people, giving them goods in return for being helped to replicate (like flowers)...
- The **Replicating Rapid** Prototyper Project



# *Rapid Prototyping*



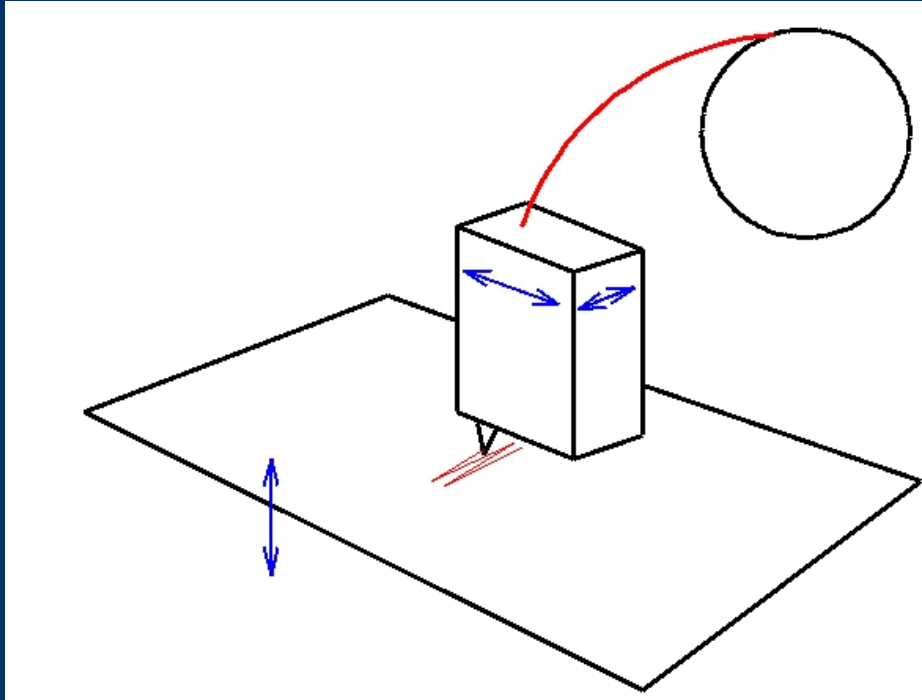
David Jones -  
“Daedalus” - 1974



Wyn Kelly Swainson patent  
published in 1977.

Now many different technologies.

# *FDM rapid prototyping*

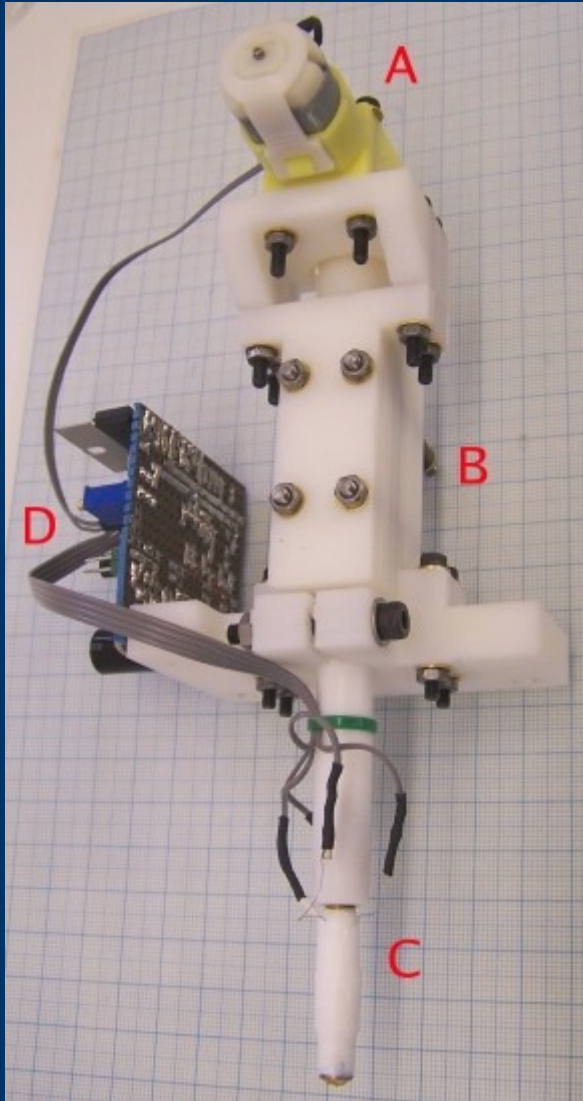


**Fused Deposition Modelling**





# Rapid-prototyped FDM write-head

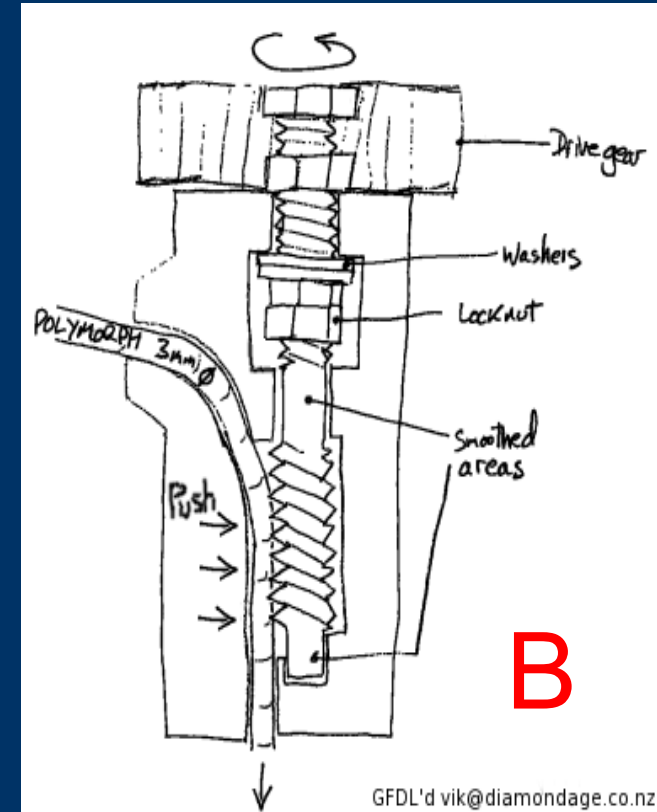


**A** – geared motor

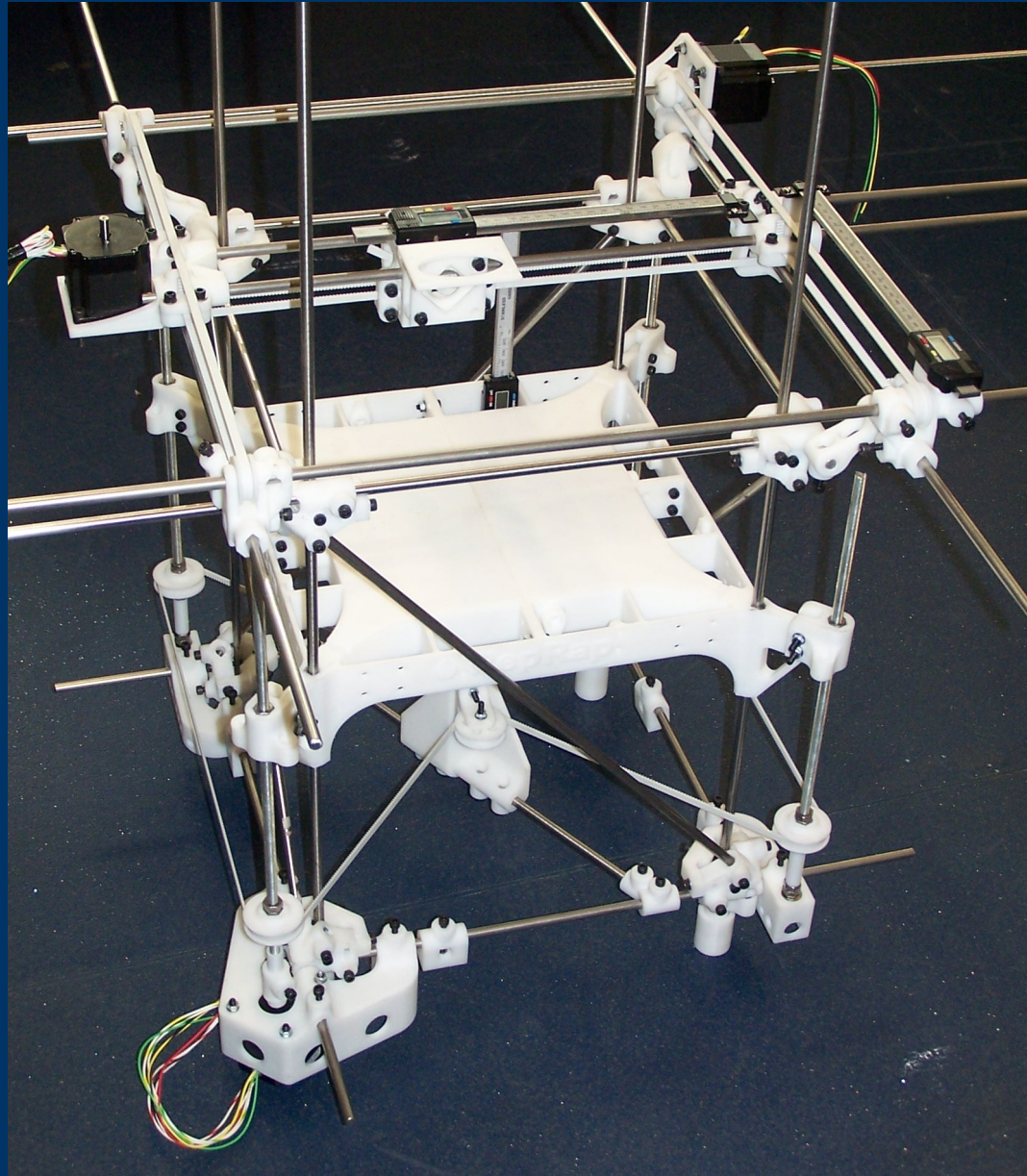
**B** – screw drive

**C** – heated extruder

**D** – electronics

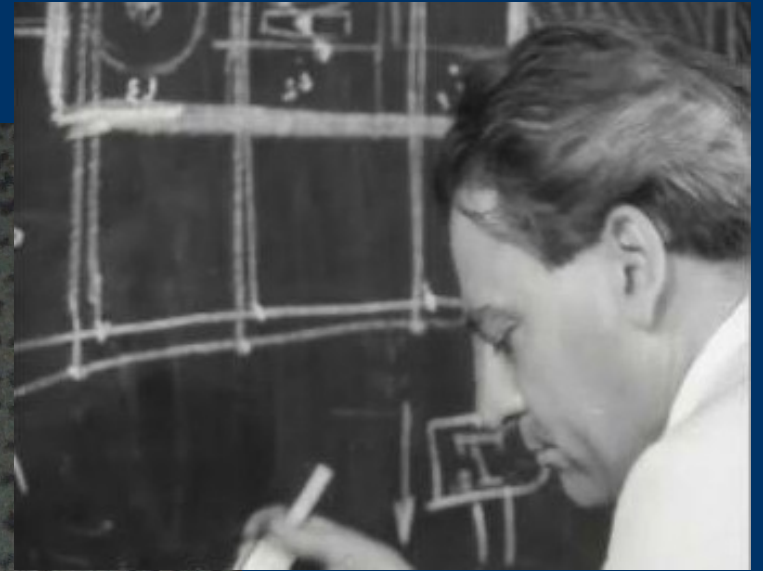
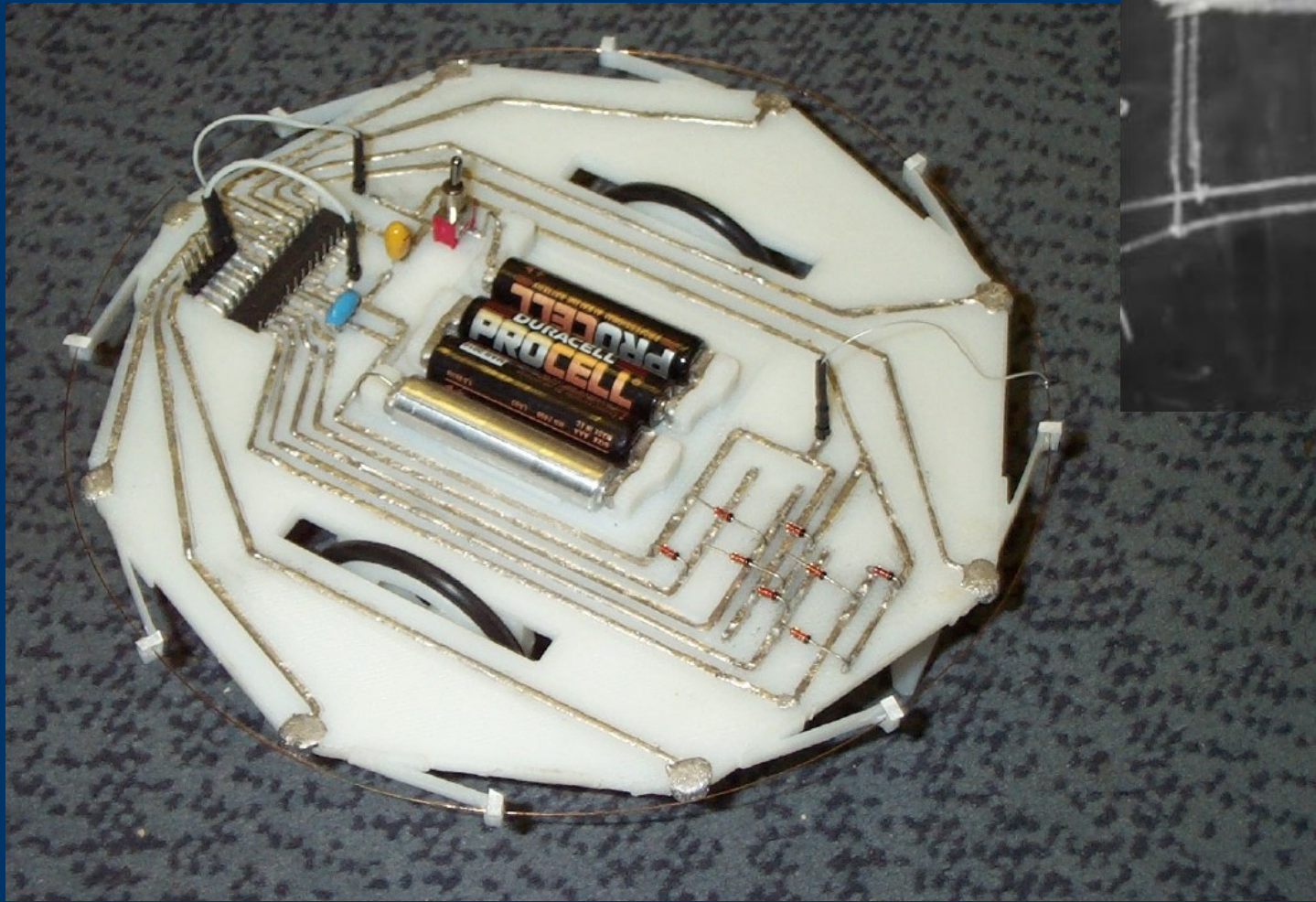


# *Rapid-prototyped Cartesian robot*





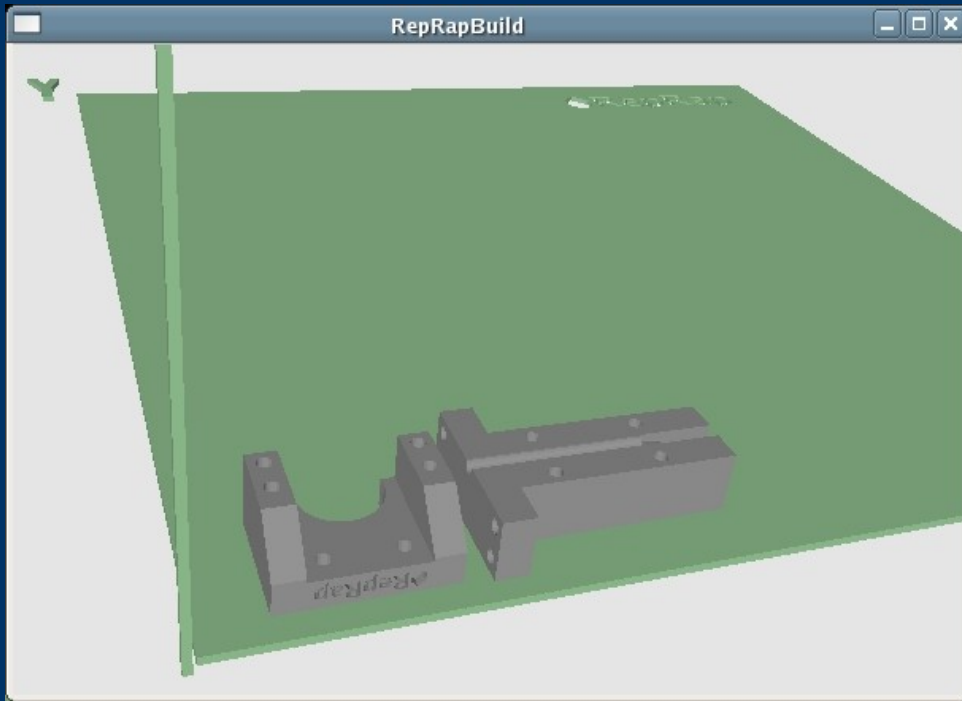
# *Rapid-prototyped electric circuits*



John Sargrove

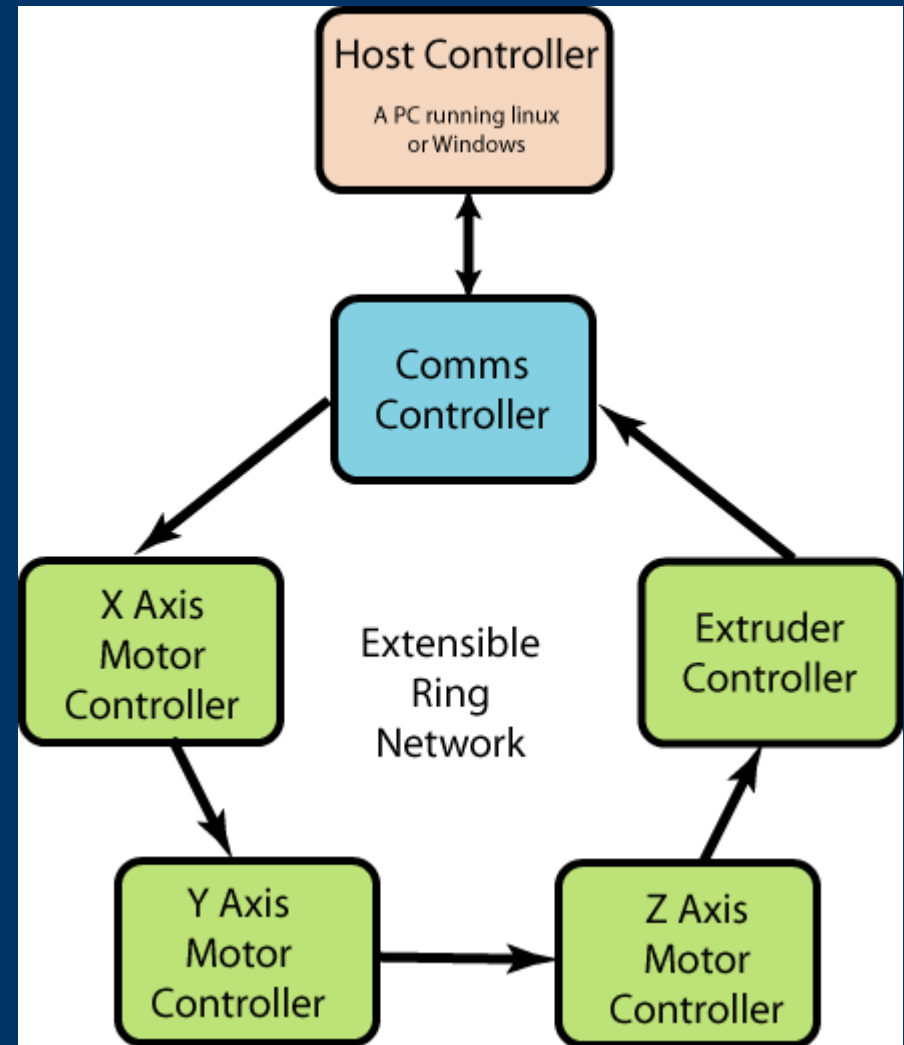


# Software and communications



PC : Java

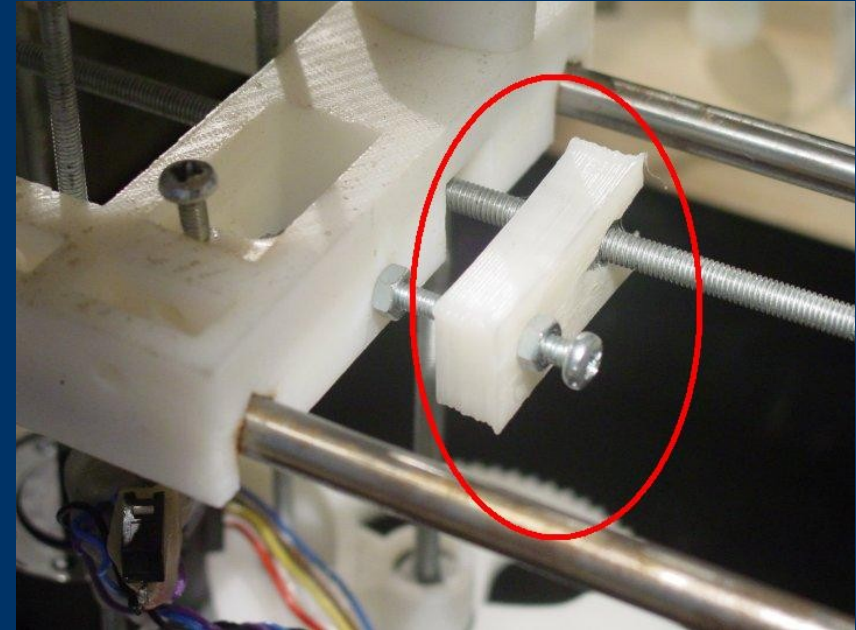
Microcontrollers : C



# *Does it work?*



Testbed machine



13 September 2006

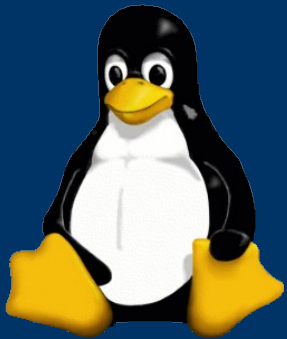
*Hubris*

What will happen if RepRap takes off?





# *Start by making RepRap open-source*



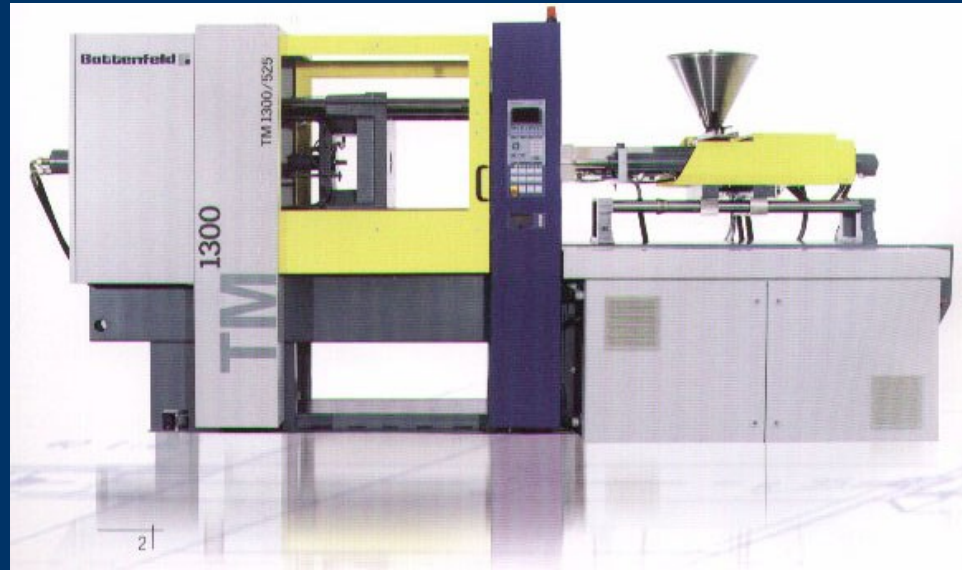
Linux



- The GNU General Public Licence
- People's generosity
- Internet-based cooperatives of volunteers
- Ubiquitous computer ownership



# *Exponential growth*

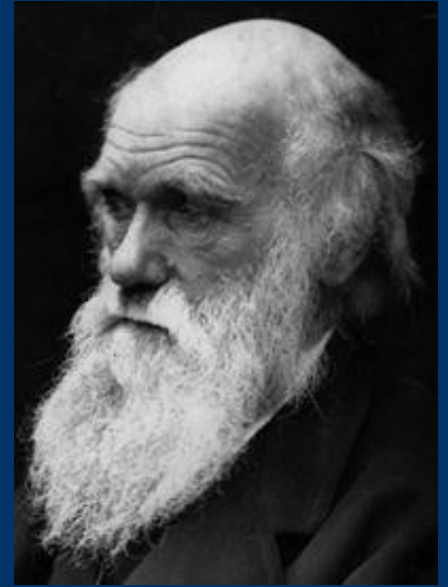


10,000 per hour

Say the RepRap machine takes one day to copy itself, and to make one comb...

# Evolution

The CAD designs (genotype) have to be available with the RepRap machine (phenotype) for it to be able to copy itself.



- People will improve the design.
- Some improvements will be posted back on the Web.
- Old machines can make new designs.
- Artificial selection – speed, simplicity, accuracy, fewer added parts...
- 'Speciation', and runaway symbiotic selection.



# *Economics*

It doesn't matter how much the first RepRap machine costs, all the rest will cost:

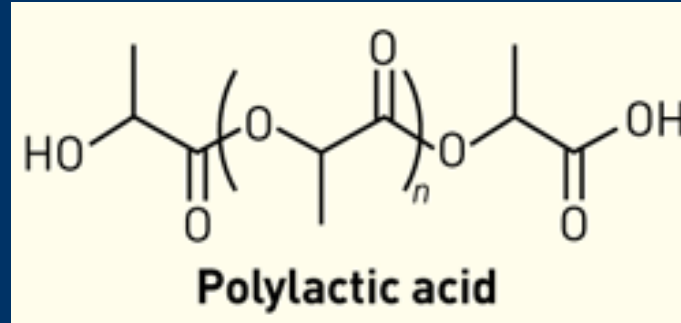
$\$ \text{ raw-materials} + \text{ assembly-time.}$

- Once you have one, you can have any number.
- No one can make money by selling RepRap.
- Target cost of raw materials, motors, chips etc:

**\$400**



# *Economics*



- Material supply - biomass.
- Bringing manufacturing to the poorest people.
- Making manufacturing like agriculture.
- Recycling.



# *Two Potential RepRap products*



Many more on the RepRap website contributed by the public.



# *The Open Phone*

- TUX phone
- Free open design on the web
- Each phone is also a base station
- Game theory:
  1. Attenuate signal with proximity
  2. Relay signals from neighbours
  3. Check new connections – only relay if 1 & 2 satisfied



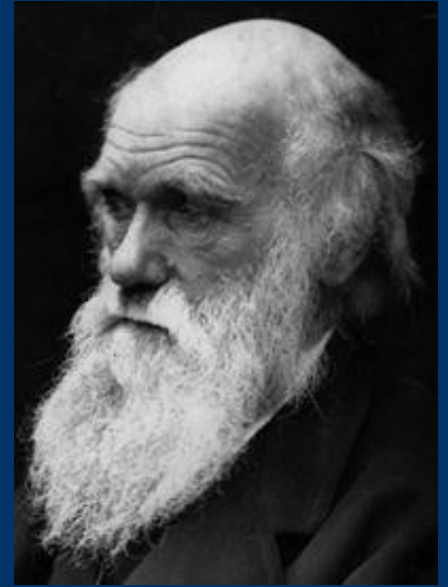
# *Open Pharma*



- Year's supply of a new drug: \$40,000 and rising
- Cost of a desktop synthesiser: \$200,000 and falling
- People can make patented things themselves (UK)
- Have RepRap make the synthesiser
- Open-source drug design, development, and testing

# *Darwinian Engineering*

- 19<sup>th</sup> century: steam power
- 20<sup>th</sup> century: electric data
- 21<sup>st</sup> century: Darwinian engineering
- History doesn't happen in centuries...

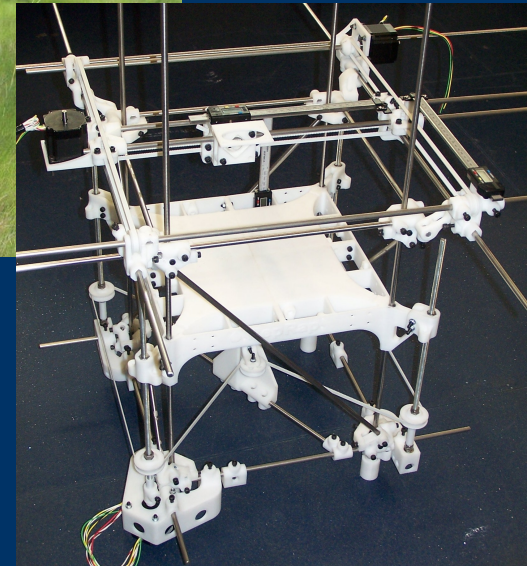
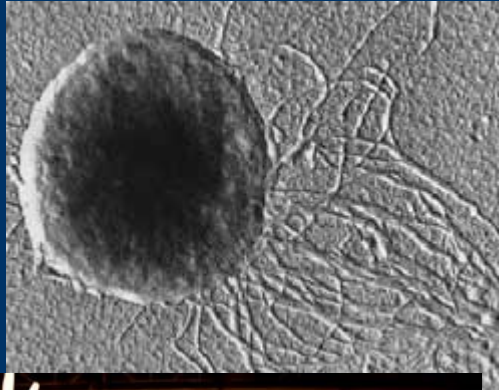
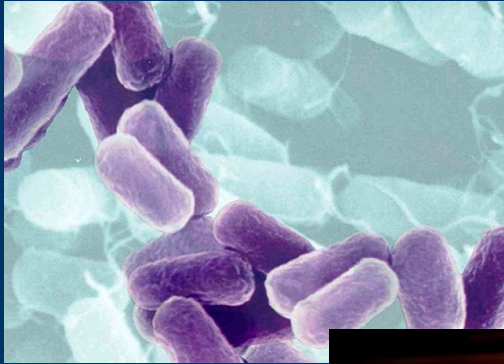


Darwinian engineering is the design of *self-replicating machines* and and their *extended phenotypes* so that they collectively exhibit an *evolutionarily stable strategy*.



# Self-replicating machines

- Bacteria, archaea, eukarya



- Artificial replicators



# *Extended phenotype (Dawkins)*

- Phenotype



- Extended phenotype



# *Evolutionarily Stable Strategy (Maynard-Smith)*

An ESS is a (set of) phenotype(s) that cannot be invaded by a mutation.



	Hawk	Dove
Hawk	-25	+50
Dove	0	+15

ESS:

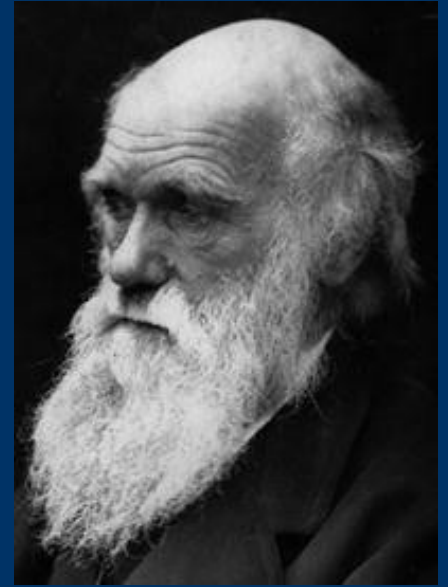
Hawk : Dove = 3 : 2

- Every ESS is a Nash equilibrium.
- Not every Nash equilibrium is an ESS.



# ***Darwinian Engineering***

The design of self-replicating machines and their extended phenotypes so that they collectively exhibit an Evolutionarily Stable Strategy.

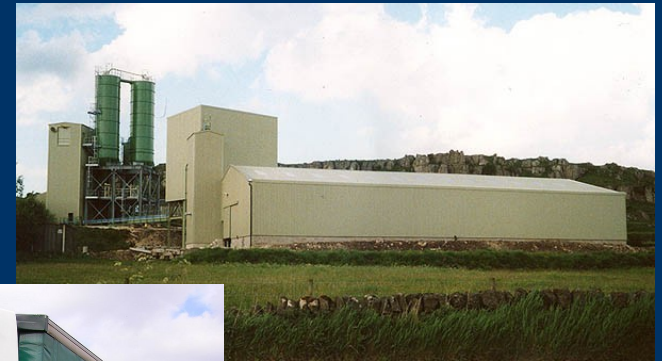


- RepRap is an example.
- Self-replicating machines: People, RepRap
- Phenotype behaviour: helping to copy; making useful stuff
- ESS: Symbiosis, like the insects and the flowers

# The Future?

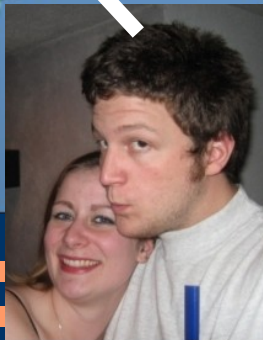
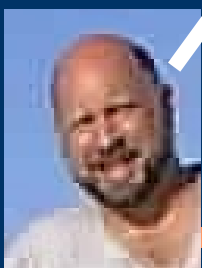
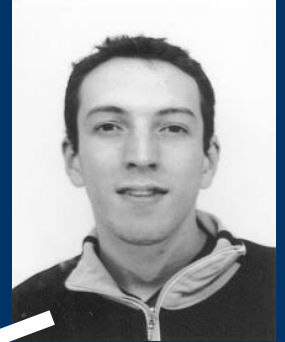
A tenth-generation RepRap in every home?

- Fewer factories?
- Less goods transport?
- Less need for money?



# Acknowledgments & the Team

- Nuffield Foundation
- EPSRC
- Bath University IMRC



*Project website:*

<http://reprap.org>