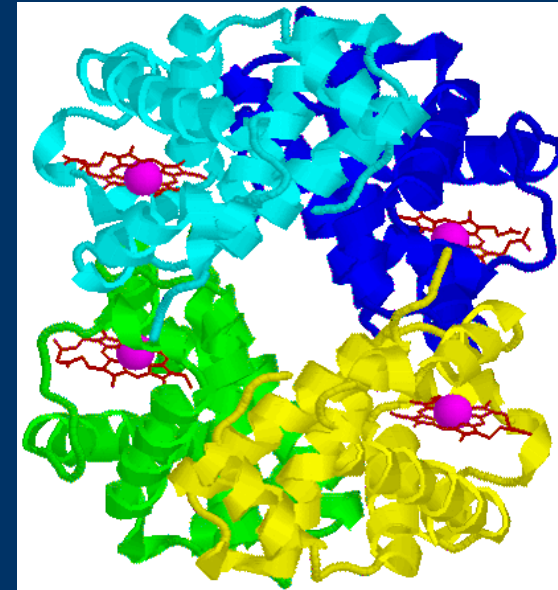


RepRap
*the open-source self-copying 3D
printer*

Adrian Bowyer
Bath University, U.K.

Go Open Oslo, 9 April 2008

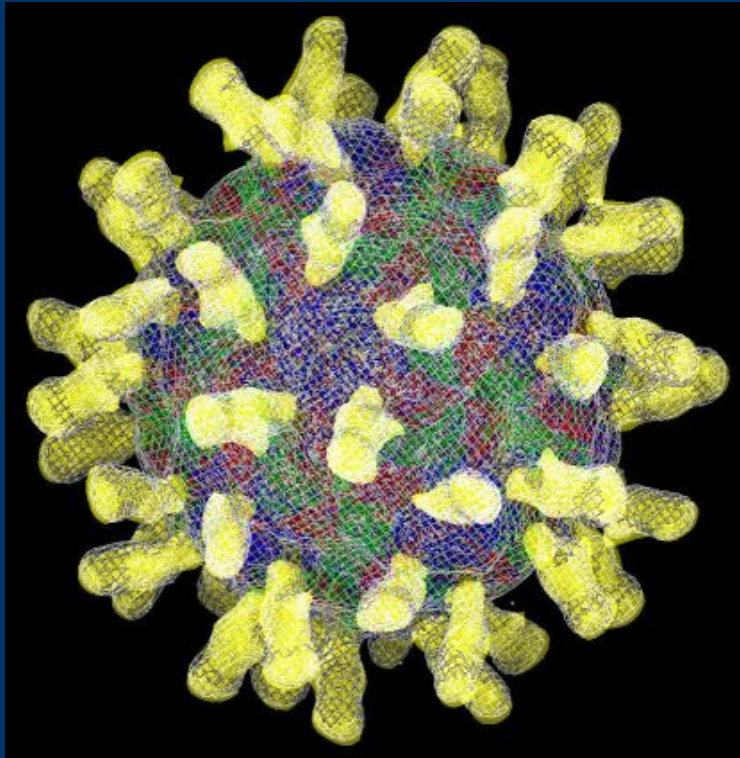
The two key biological phenomena



Self Replication

Self Assembly

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

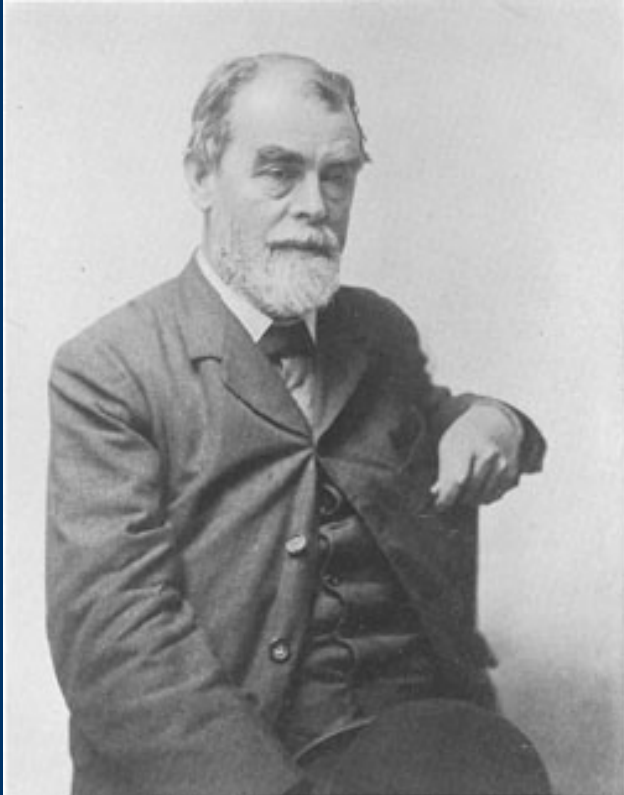


Rhinovirus

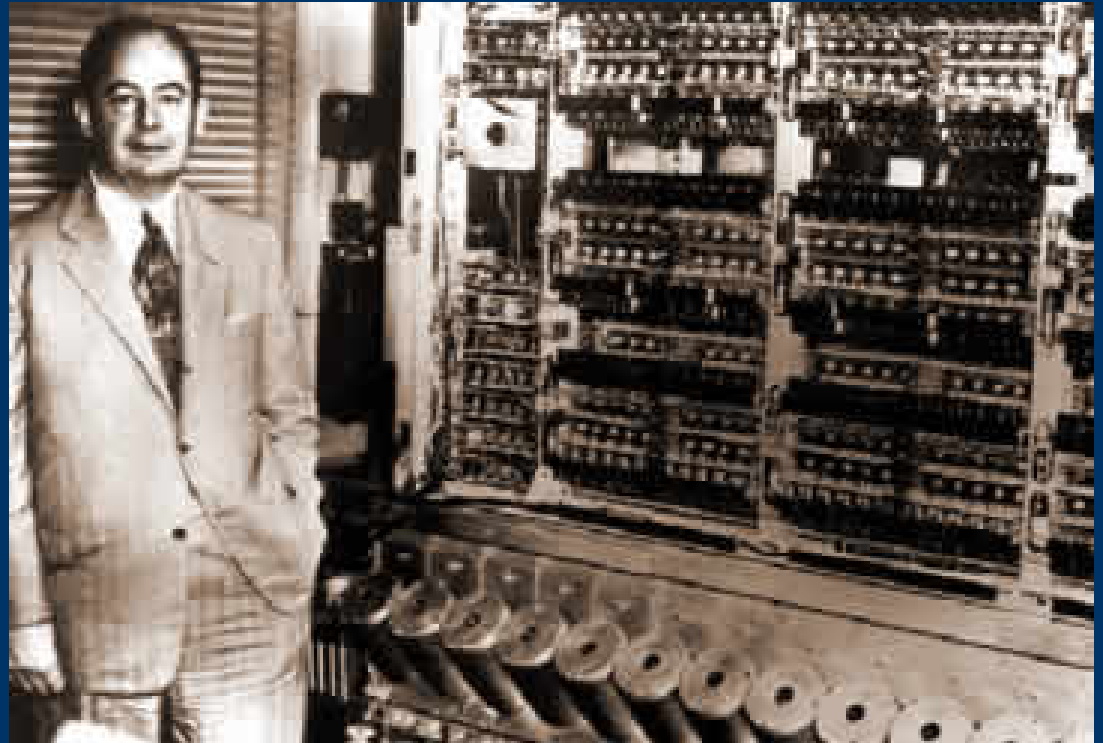


H. sapiens

Artificial self replicators & assemblers



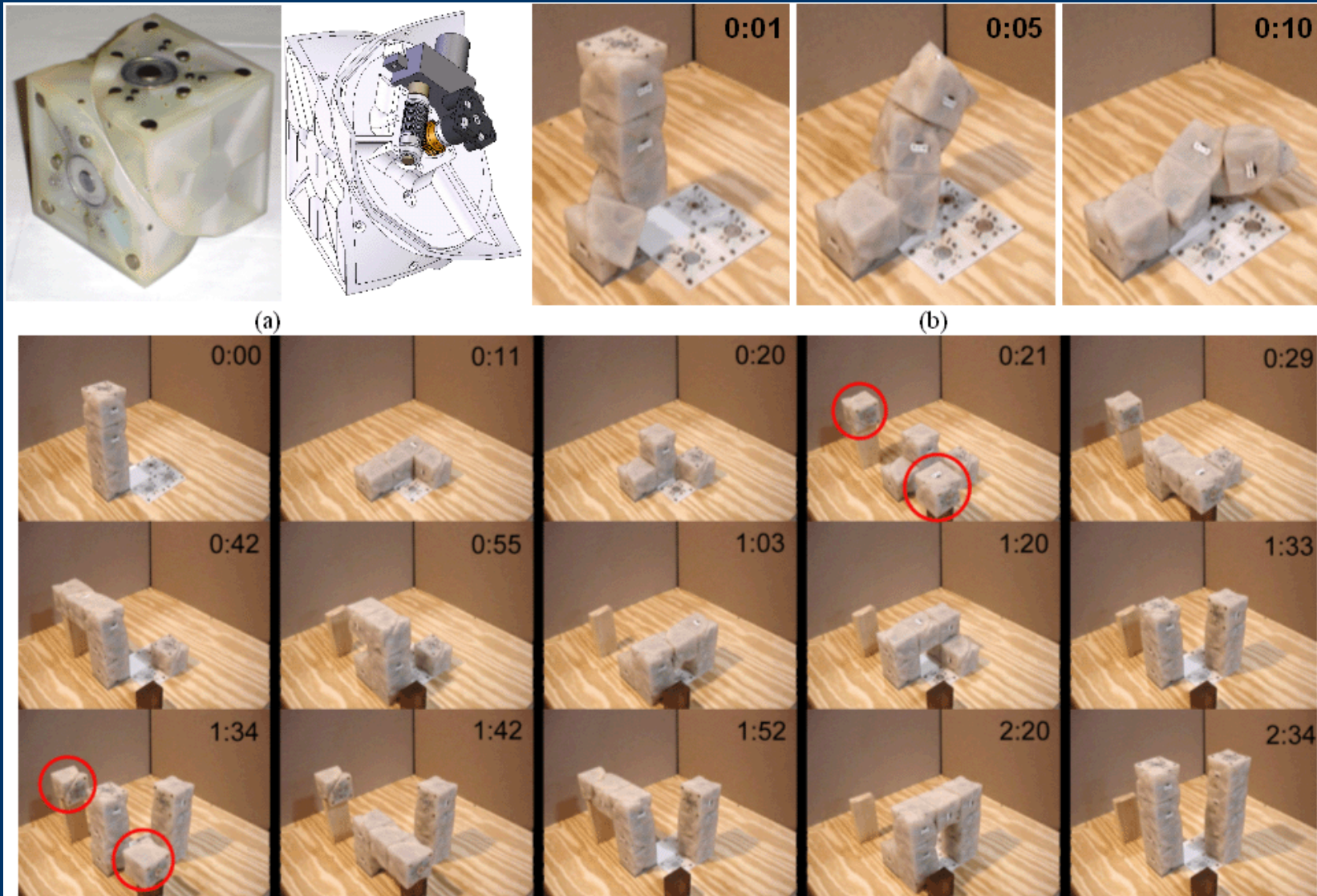
Samuel Butler (1870s)



John von Neumann(1950s)



Artificial self replicators & assemblers



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

Symbiosis



nectar <> reproduction

Symbiosis



nectar <> reproduction

Symbiosis

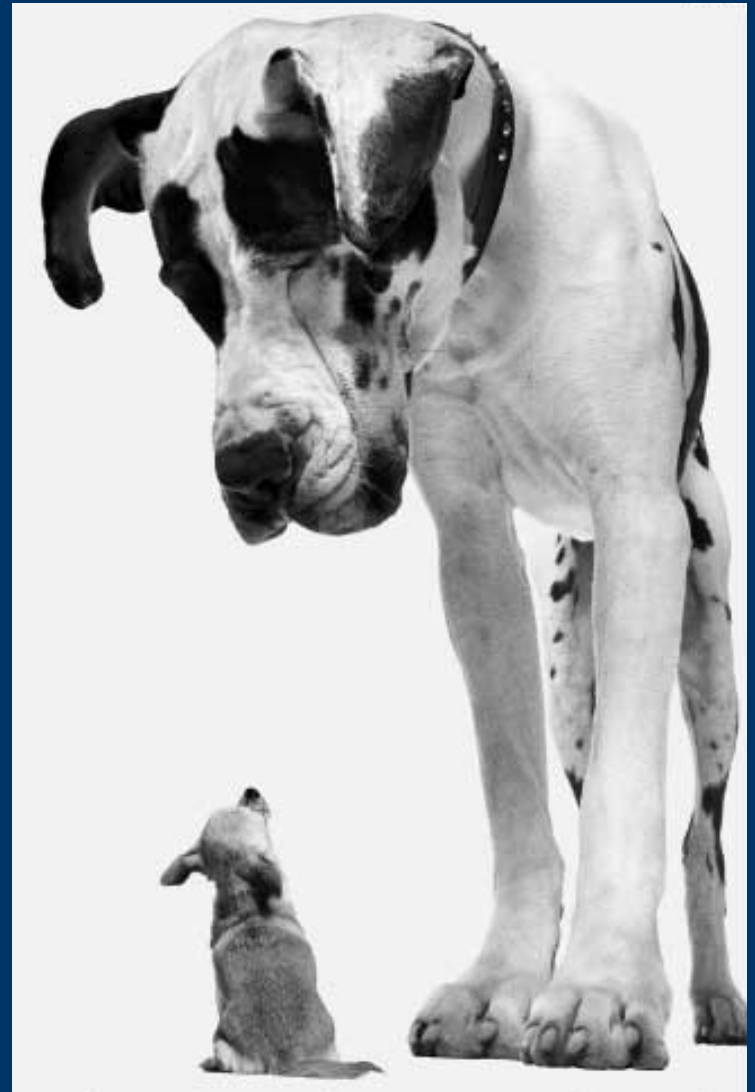
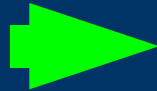


nectar <> reproduction

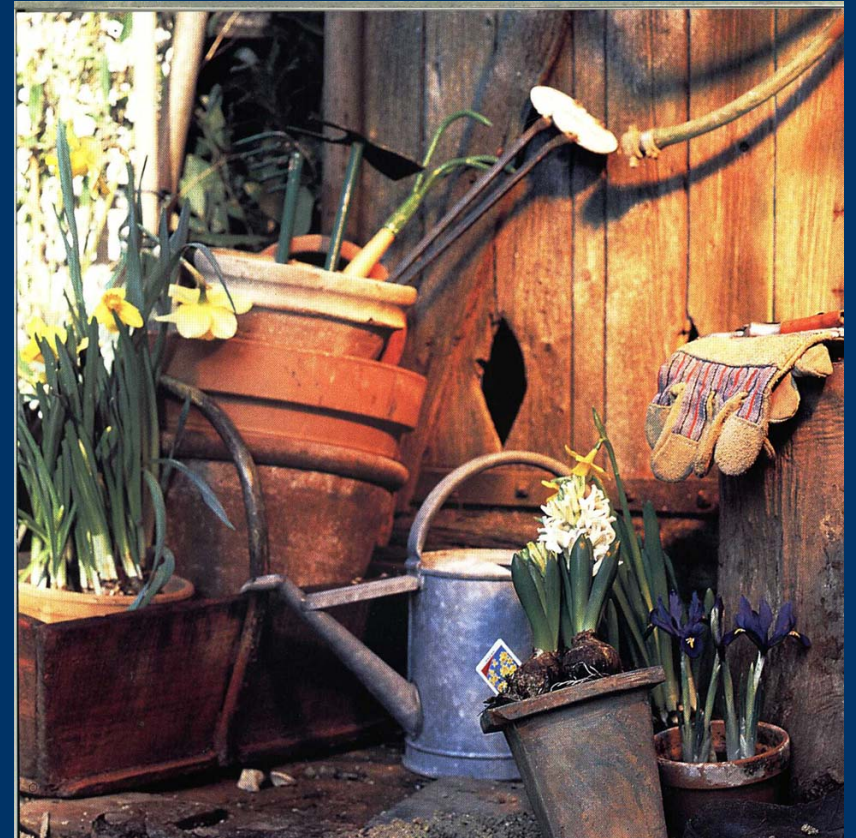


cake <> reproduction

Humanity's most advanced technology



Genetic engineering equipment



Suppose we made a machine that:

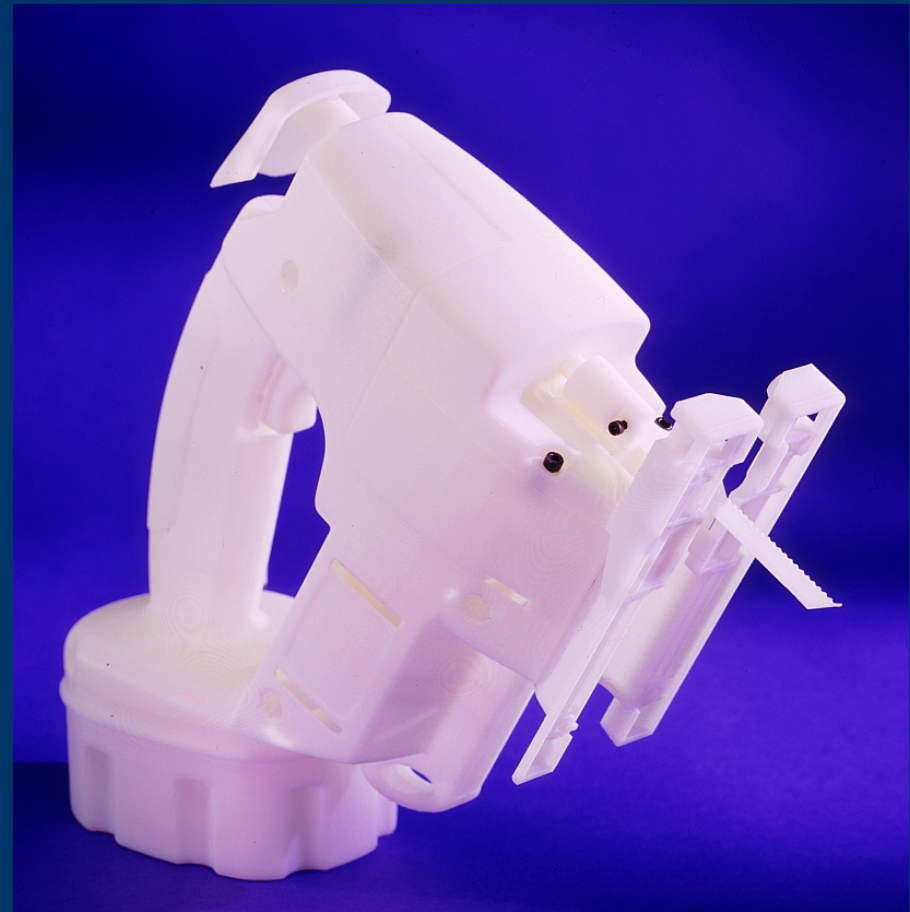
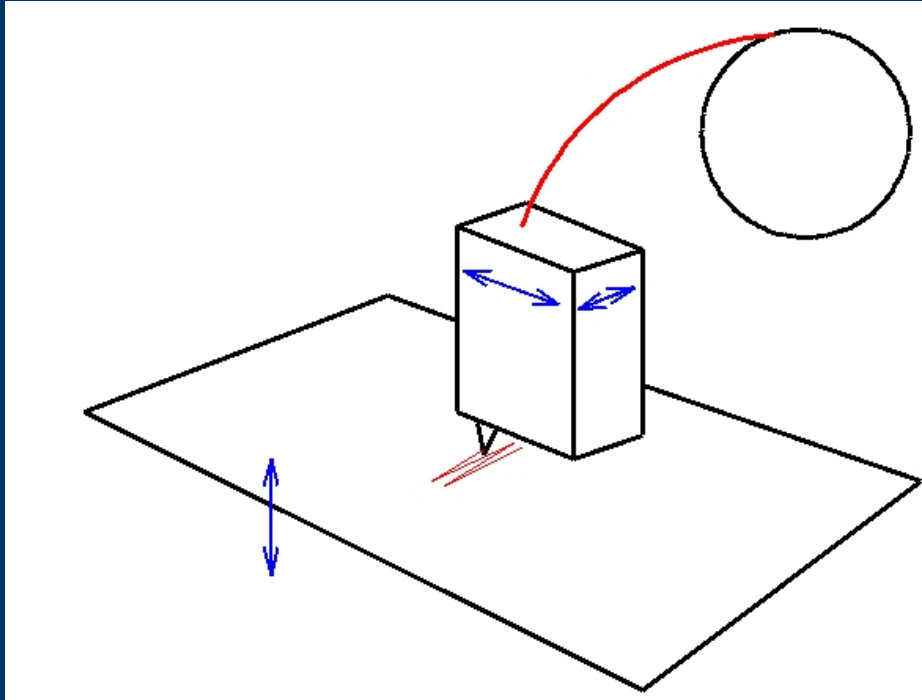
- Self-replicated almost all its parts
- Existed symbiotically with people, giving them goods in return for being helped to replicate (like flowers)...
- Evolved by breeding

Suppose we made a machine that:

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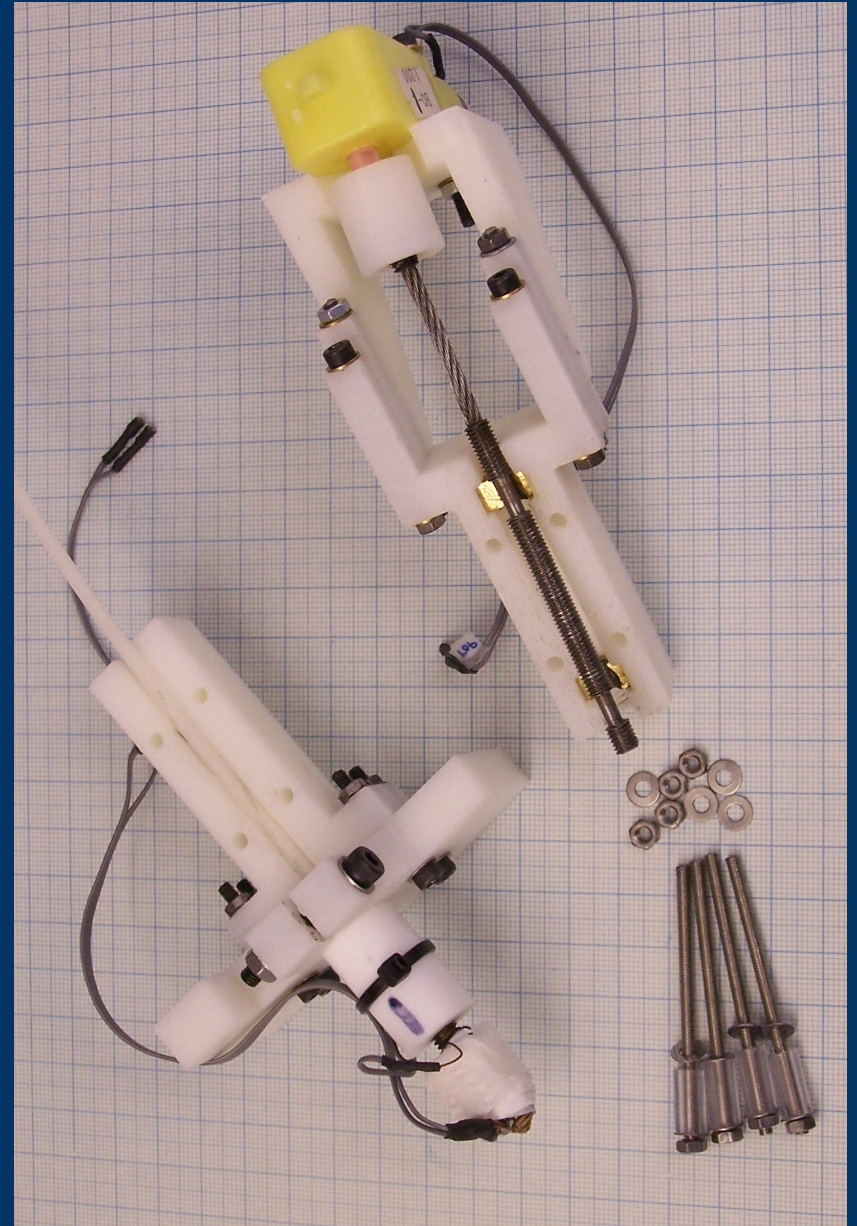
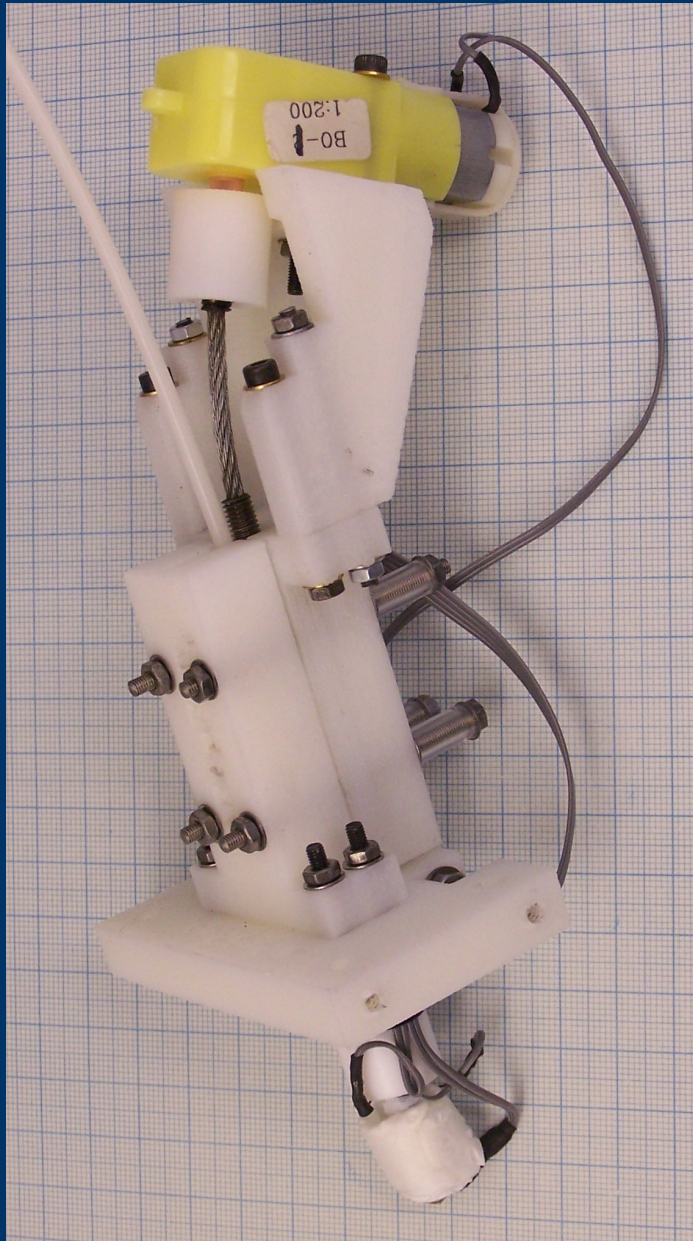
RepRap - The **Replicating Rapid** Prototyper

FFF rapid prototyping

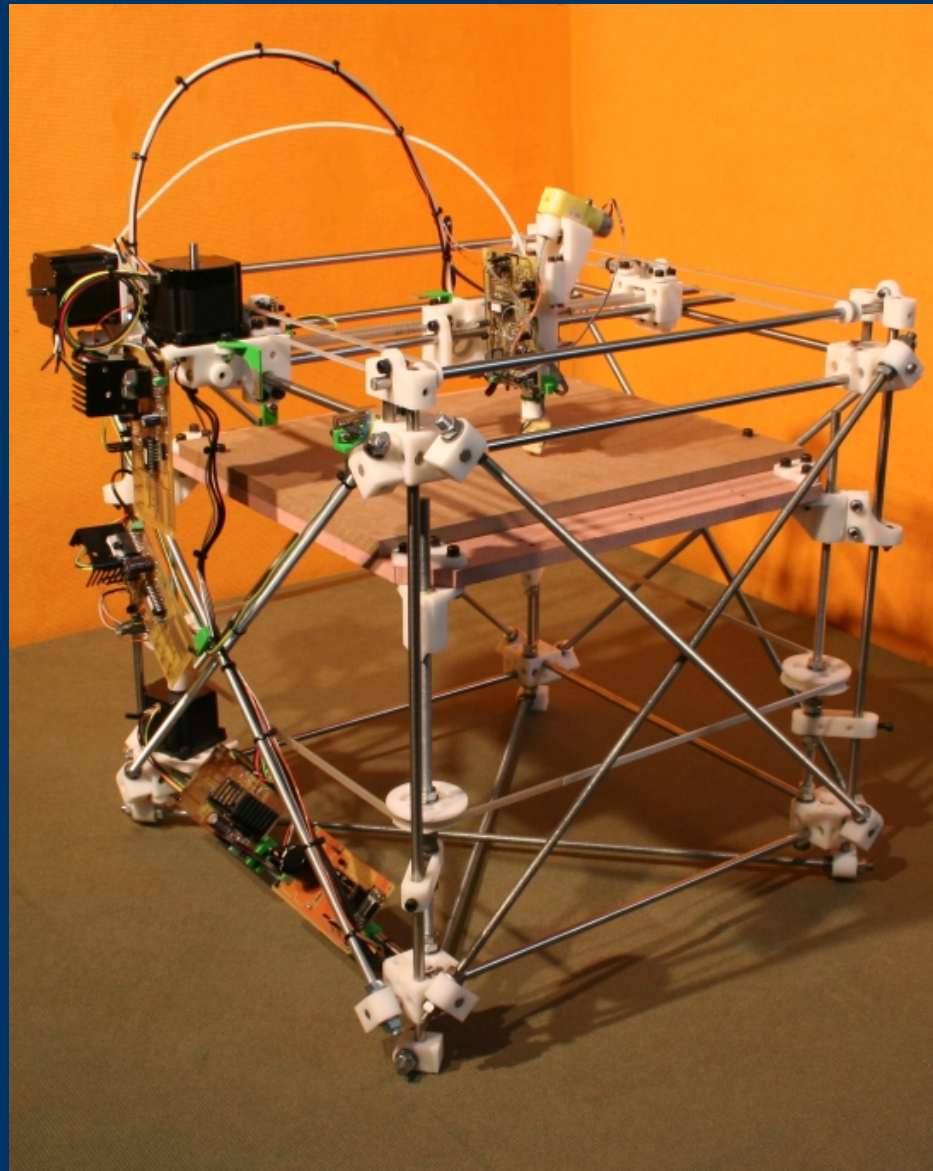


Fused Filament Fabrication

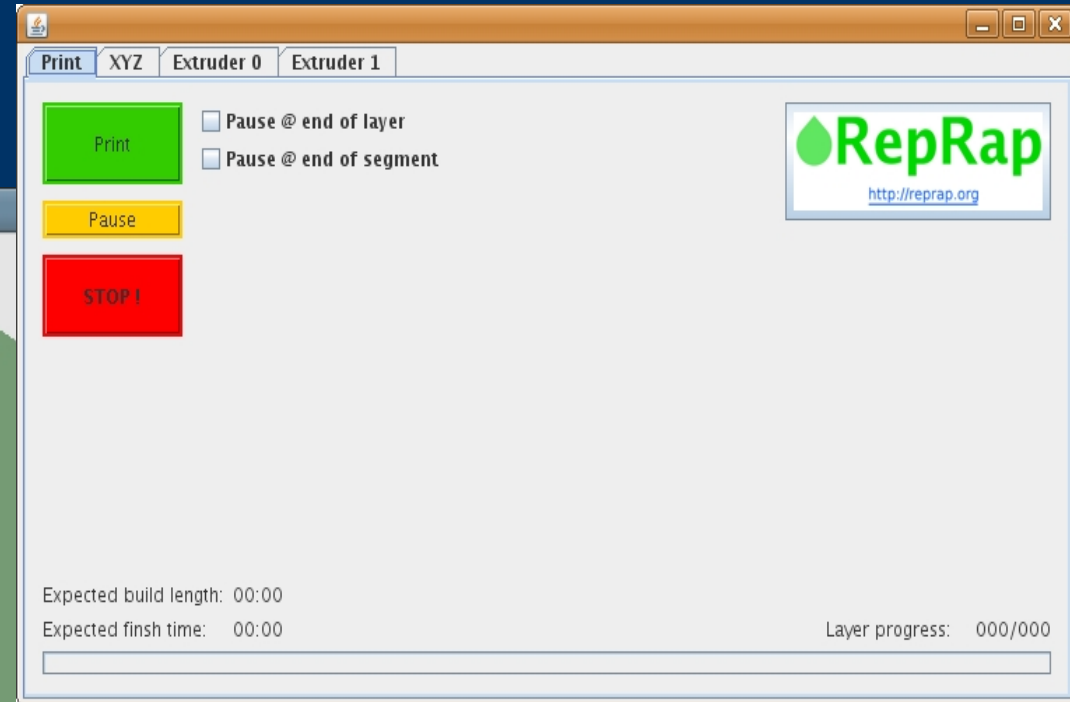
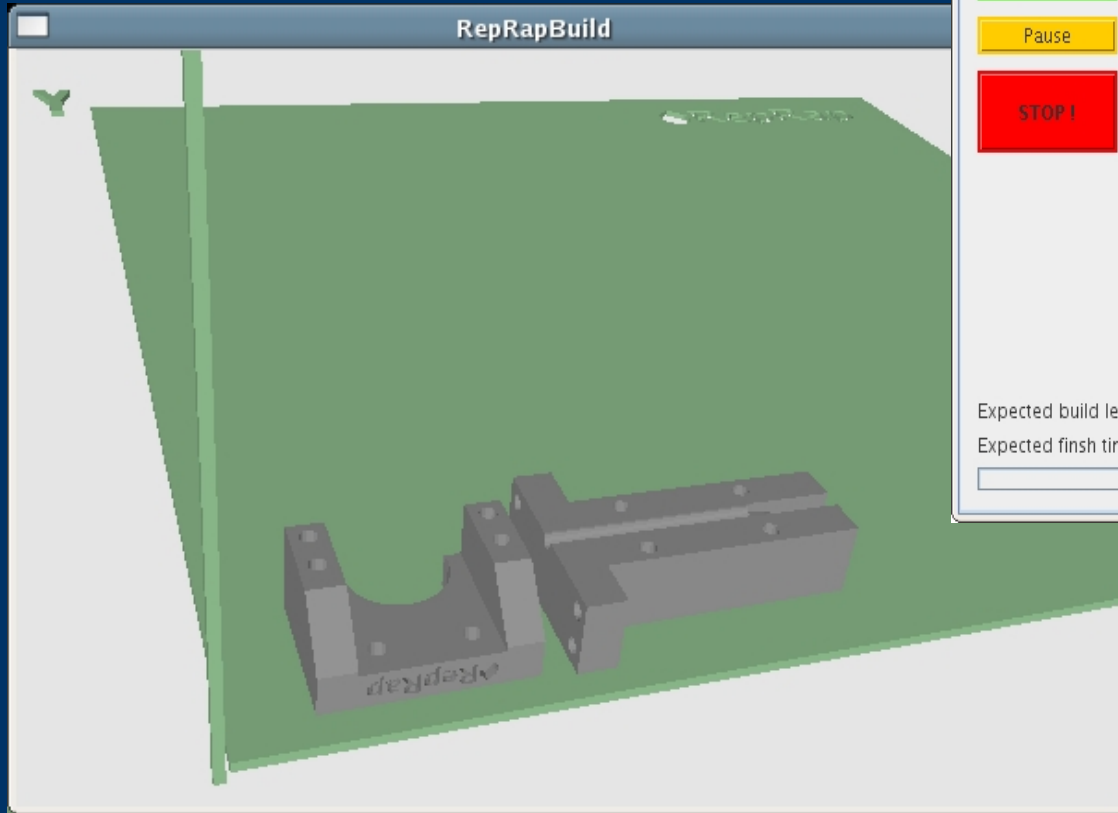
Rapid-prototyped write-head



Rapid-prototyped X, Y, Z robot



Software



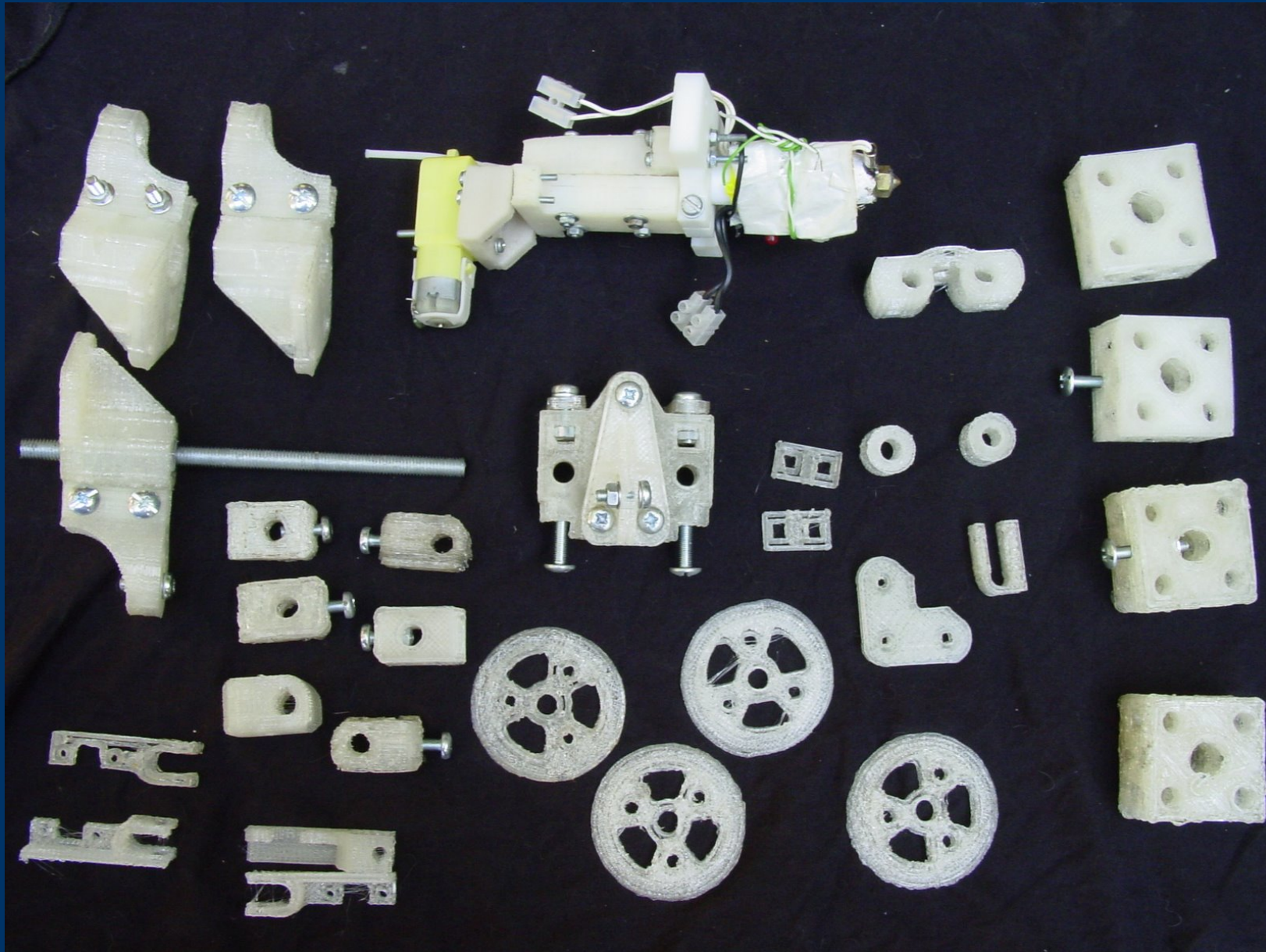
PC : Java

Microcontrollers : C

Does it work?



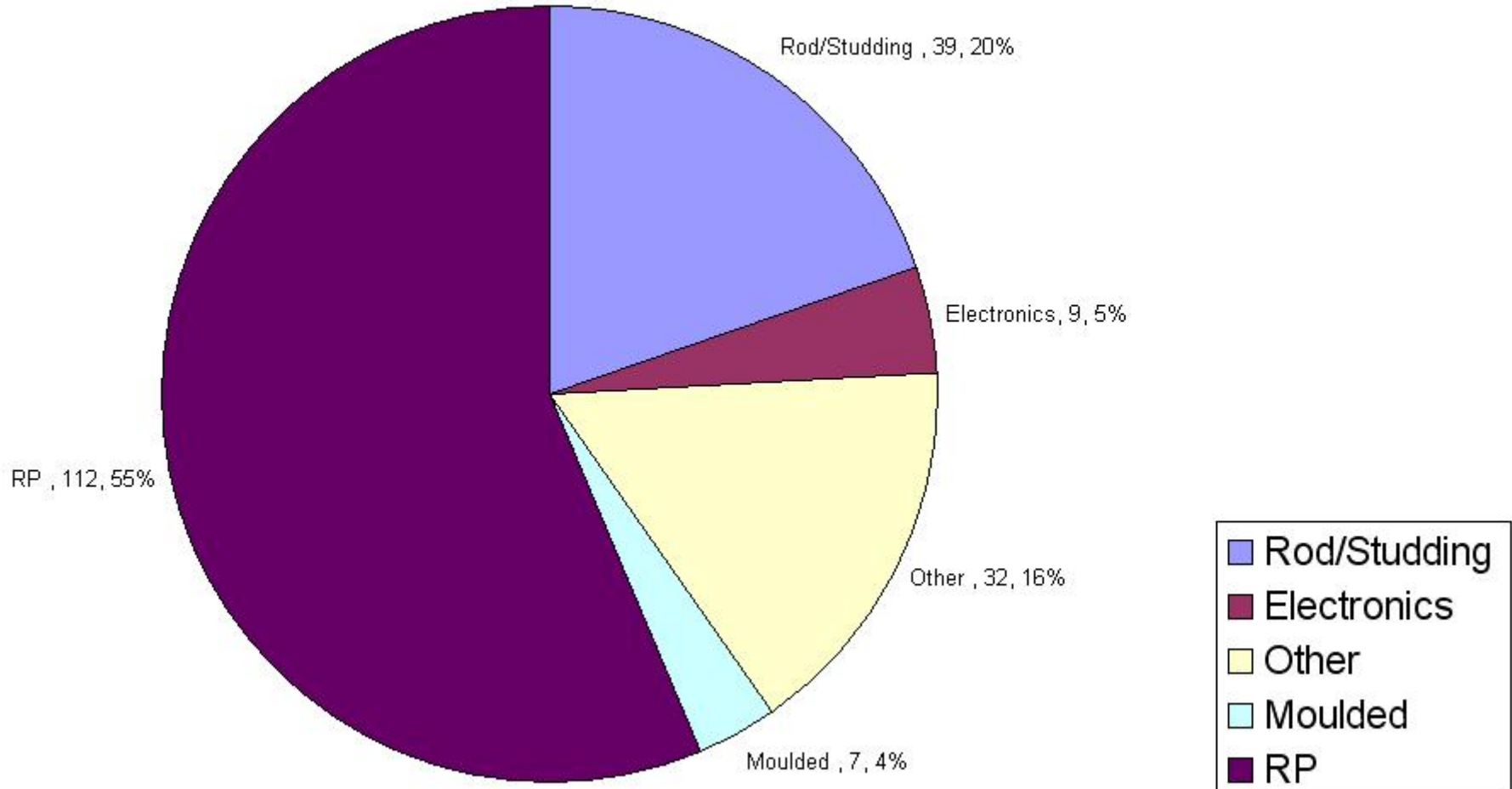
Parts reproduced at 5 Feb 2008



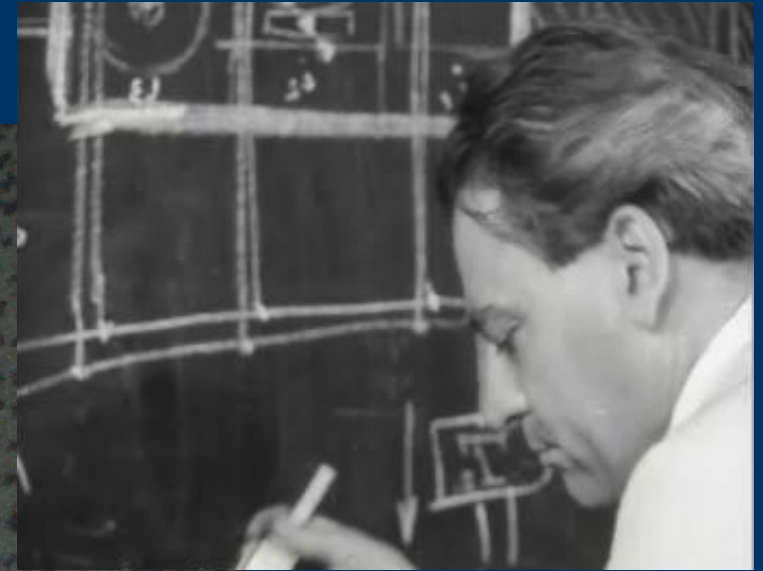
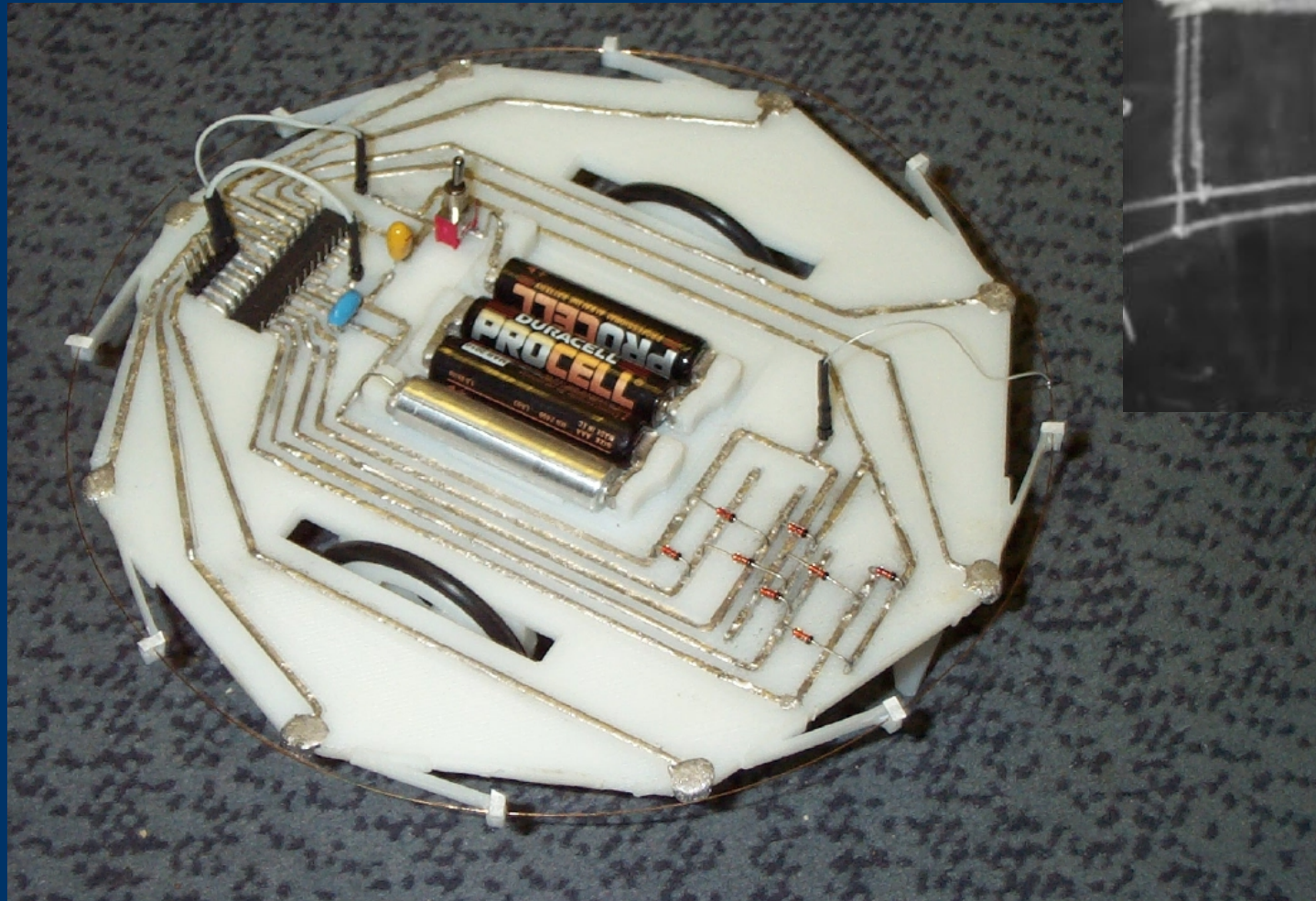
35%

RepRap part count

Part count for component types used to build Darwin including one extruder, excluding fasteners



Rapid-prototyped electric circuits



John Sargrove

Hubris

What will happen if RepRap is successful?

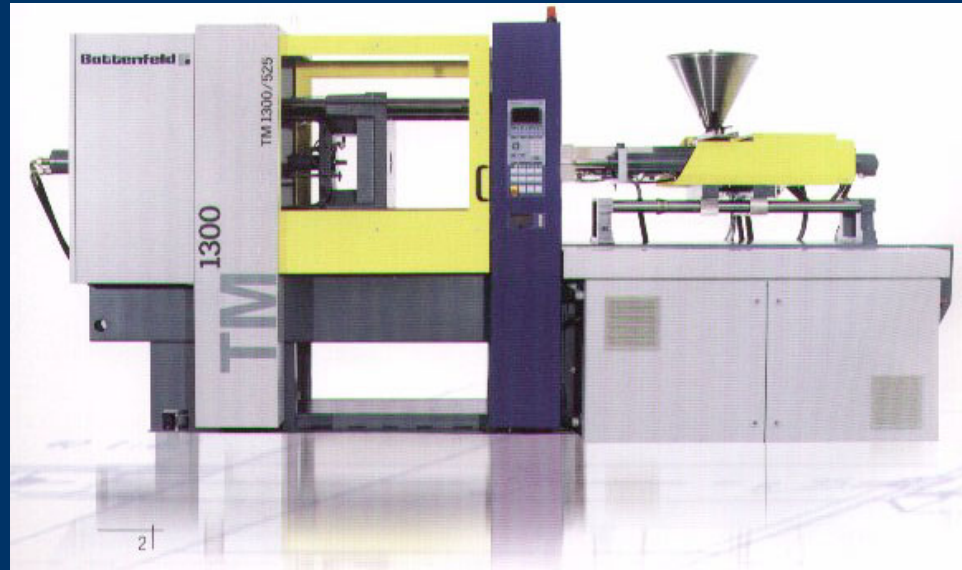
Start by making RepRap free hardware



Linux



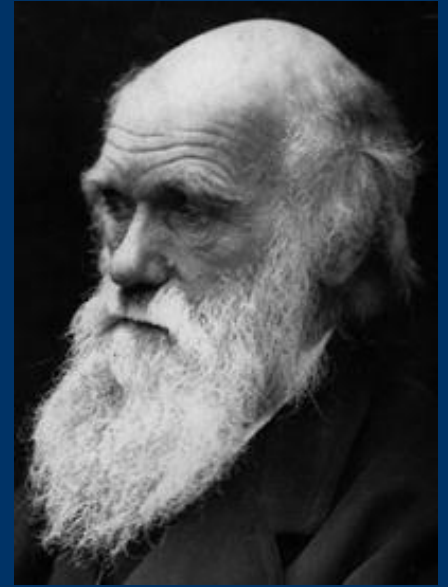
Exponential growth



10,000 per hour

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

Evolution



- 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...

Economics

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

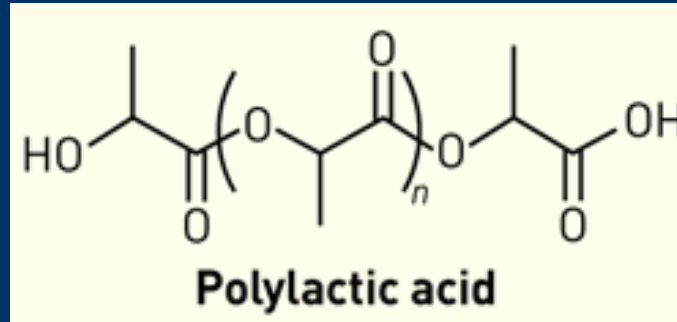
raw-materials + assembly-time.

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

NOK 3000



Environment

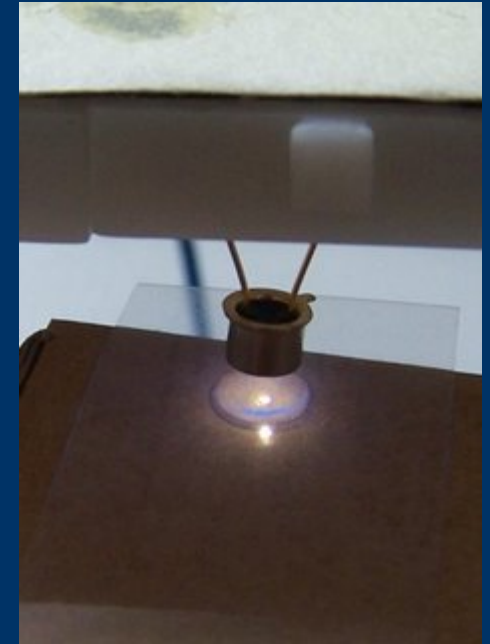


- Material supply - biomass.
- Bringing manufacturing to the poorest people.
- Making manufacturing like agriculture.
- Recycling.



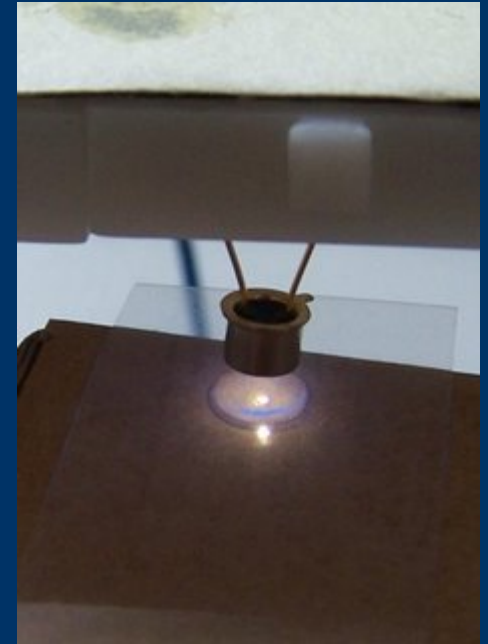
Environment

- Sustainable Composites Ltd.
- Plant-sourced UV resin.
- Parts **NON**-bio-degradable.



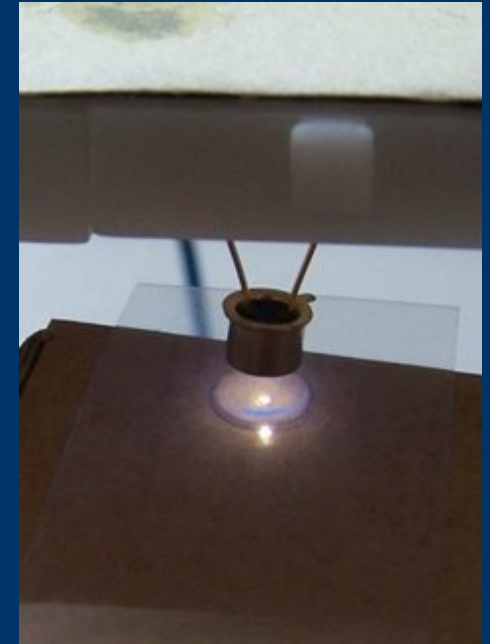
Environment

- Sustainable Composites Ltd.
- Plant-sourced UV resin.
- Parts **NON**-bio-degradable.



Environment

- Sustainable Composites Ltd.
- Plant-sourced UV resin.
- Parts **NON**-bio-degradable.
- Locks up CO₂ for geological time.



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: NOK 200,000 and rising
- Cost of a desktop synthesiser: NOK 1,000,000 and falling
- People can make patented things for themselves
- Have RepRap make the synthesiser
- Open-source drug design, development, and testing

The Future?

Almost everyone in the developed world runs their own:

- CD pressing plant



The Future?

Almost everyone in the developed world runs their own:

- CD pressing plant



- Photographic laboratory



The Future?

Almost everyone in the developed world runs their own:

- CD pressing plant



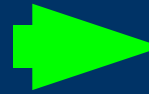
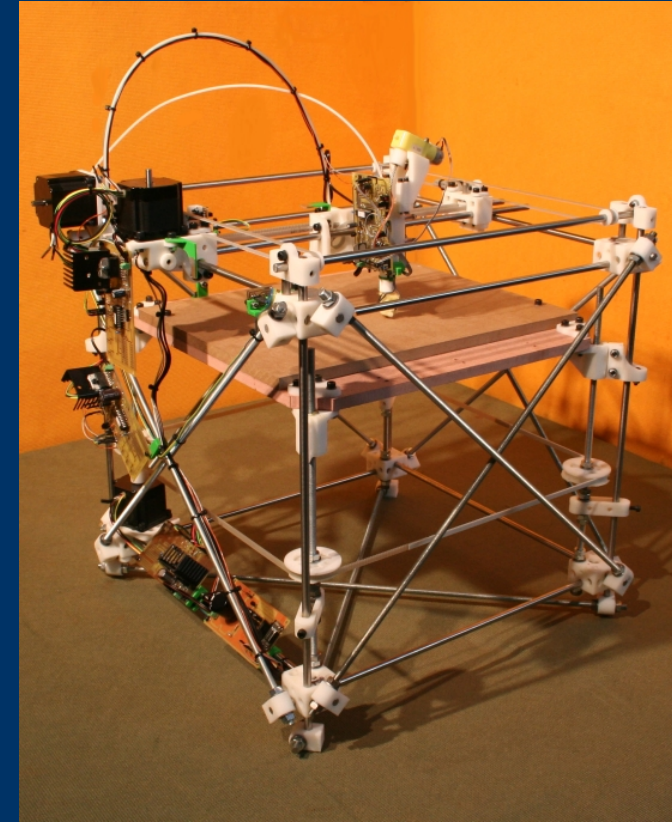
- Photographic laboratory



- Printing press



Why not their own factories?

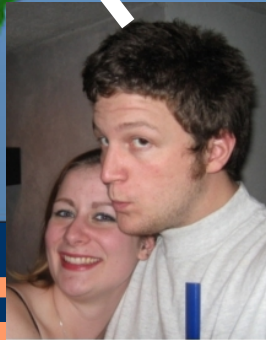
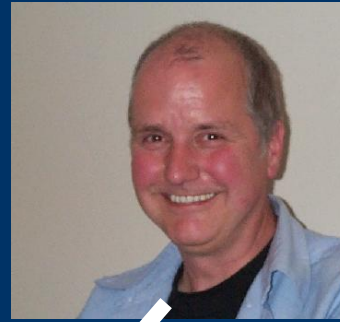


Reprappers



Acknowledgments & The Core Team

- Nuffield Foundation
- EPSRC
- Bath University IdMRC



Project website:

<http://reprap.org>

Destruction



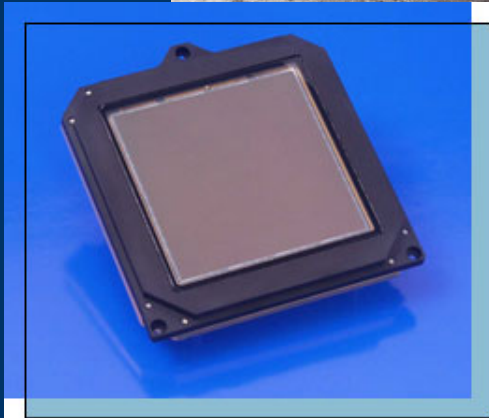
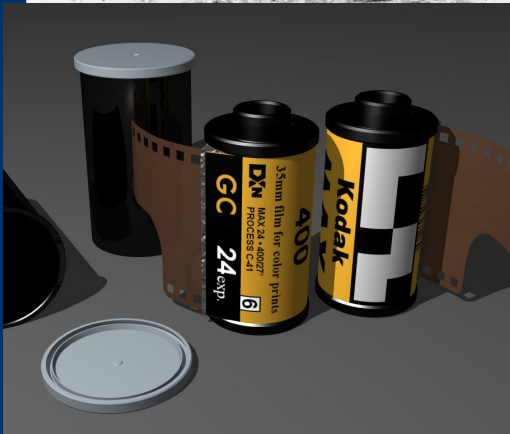
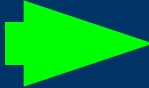
London 1943

*That never
works:*

London 2008



This always works:



Design and manufacture are neutral

- They reflect human nature



Design and manufacture are neutral

- They reflect human nature



Design and manufacture are neutral

- They reflect human nature



- Is open design and manufacture likely to be better?

The Future?

A tenth-generation replicator in every home?

- Fewer factories?



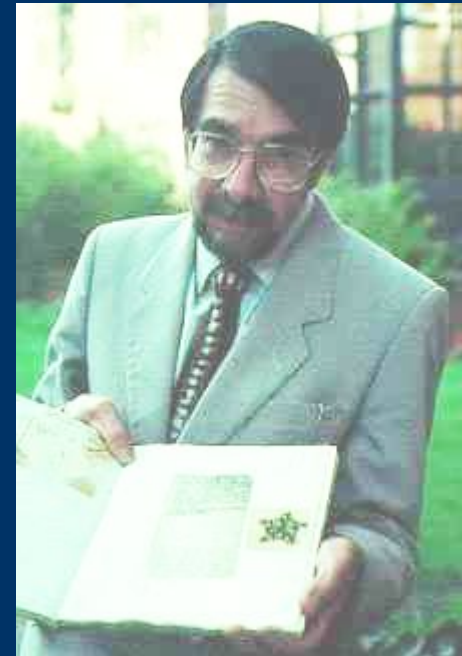
- Less goods transport?



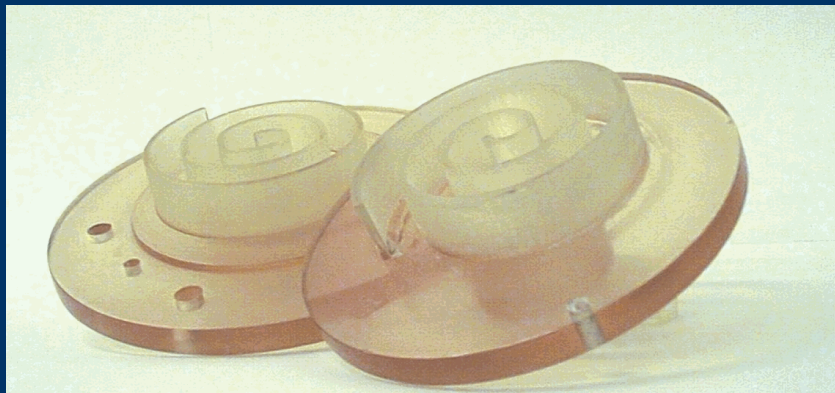
- Less need for money?



Rapid Prototyping



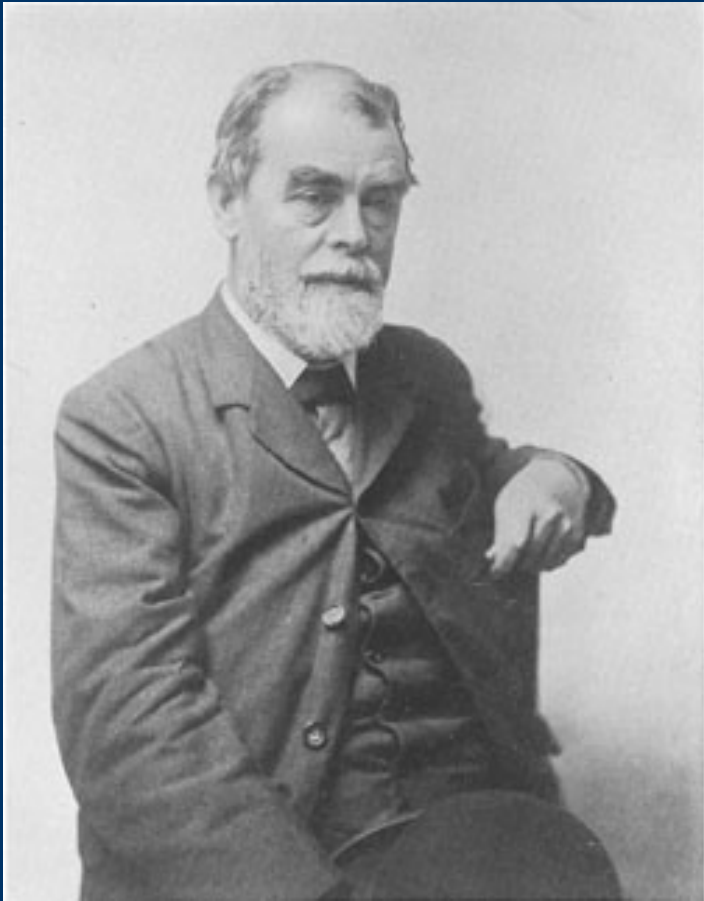
David Jones -
“Daedalus” - 1974



Wyn Kelly Swainson patent
published in 1977.

Now many different technologies.

Artificial self replicators & assemblers



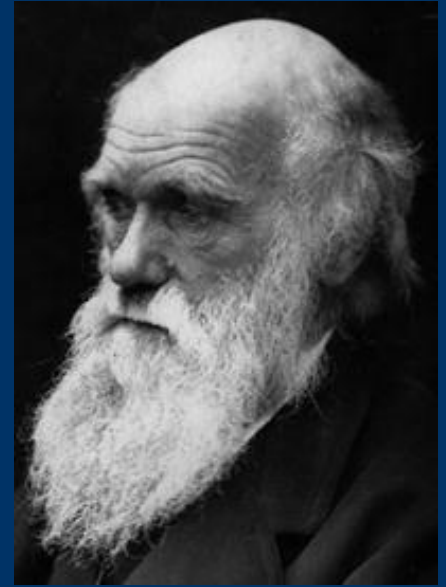
Samuel Butler

Eerewhon (1872)

“...how few of the machines are there which have not been produced systematically by other machines? But it is man that makes them do so. Yes; but is it not insects that make many of the plants reproductive, and would not whole families of plants die out if their fertilization was not effected by a class of agents utterly foreign to themselves? Does anyone say that the red clover has no reproductive system because the humble bee (and the humble bee only) must aid and abet it before it can reproduce? No one.

The humble bee is a part of the reproductive

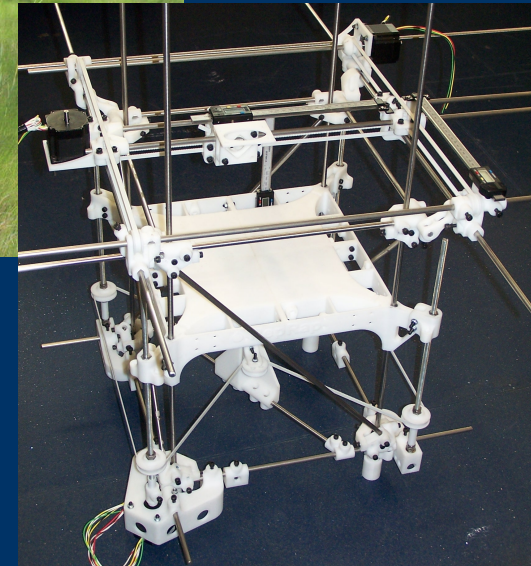
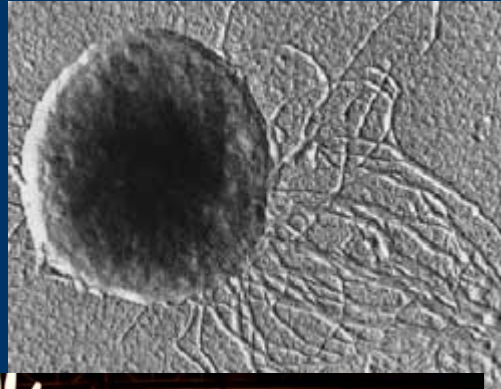
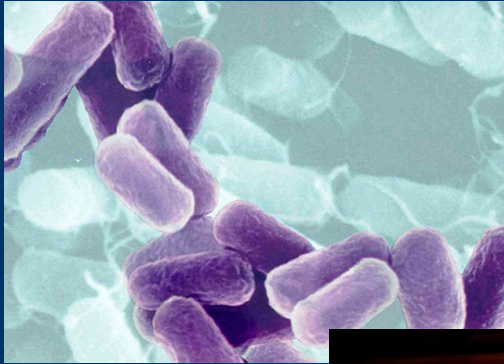
Darwinian Engineering



- 19th century: steam power
- 20th century: electric data
- 21st century: Darwinian engineering
- History doesn't happen in centuries...
Darwinian engineering is the design of *self-replicating machines* and their *extended phenotypes* so that they collectively exhibit an *evolutionarily stable strategy*.

Self-replicating machines

- Bacteria, archaea, eukarya



Extended phenotype (Dawkins)

- Phenotype

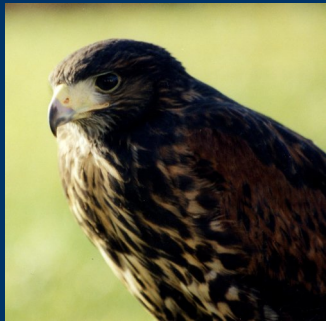


- Extended phenotype



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

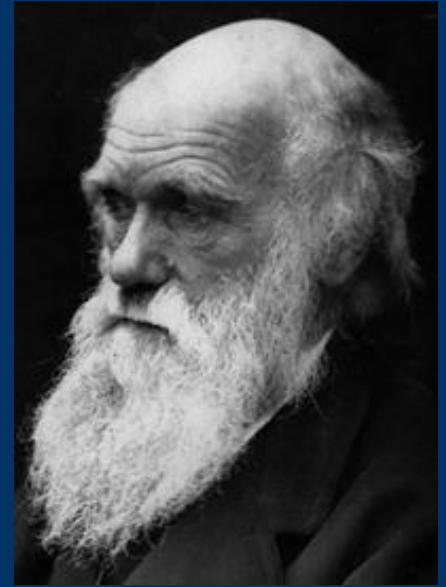
ESS:

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