Preliminary Steps toward Artificial Protocell Computation

Barry McMullin
Dublin City University
Barry.McMullin@dcu.ie

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The Team

- DCU Alife Lab:
  - Ciarán Kelly
  - Darragh O'Brien
  - George G. Mitchell
  - James Decraene
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What is a *protocell*?

- Metabolism
- Containment (membrane)
- Information (heredity?)

What is (proto-)cell *computation*?

- It *might* be at the (proto)-cell level:
  - Cell cycle control
  - Chemotaxis
  - (Differentiation? Apoptosis?)
  - . . .
- It *might* be at the multi-(proto)-cell level:
  - Nervous system
  - Immune system
  - . . .

We will concentrate on the single (proto-)cell level.

What is its $style$?

- Examples?
  - Cell signalling networks, CSN
  - Genetic regulatory networks, GRN (beyond protocells?)
- Molecular Information Processing:
  - Operators: catalysts/enzymes
  - Operands: substrates, reactants

What is its $style$?

- Real time
- Reaction *network* — somewhat like term re-writing system (but no demarcation between rules and messages)
- Reaction network "closure" matters (why?)
  - Protocell as encapsulated "replicator world"?
- Concentration matters (as does stoichiometry, thermodynamics, kinetics, catalysis ...)

How is it *programmed*?

- Evolution
- At the *protocell* level
- Layered on "replicator" dynamics at the molecular level
- (AKA "major transition")

Preliminaries (?)

- Work with an "artificial chemistry"
- Polymer family composed of two categories of monomer: labelled `0` and `1` (primary structure is binary string)
- No thermodynamics (!)
- No material conservation (!!)

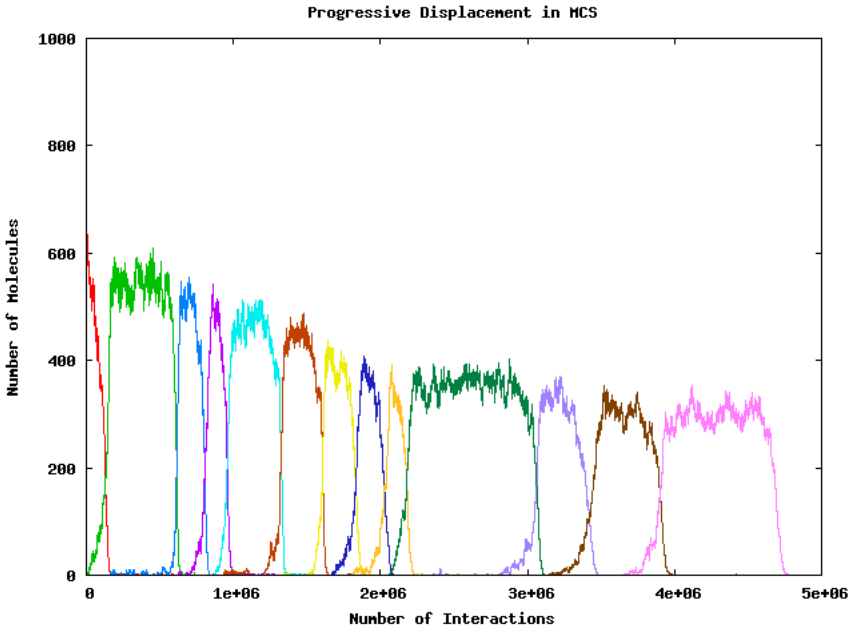
In the *absence* of protocell level . . .

- Replicator World
  - Think: ribozymes functioning as RNA replicases . . .
- Simple (!?) "replicator" dynamics
- Domination by "selfish (self-)replicator"
- Molecular level evolution á la the French Revolution:

  Longevity, Fecundity, Fidelity

  and the rest is history (?)

Data: (self-)replicator selection events



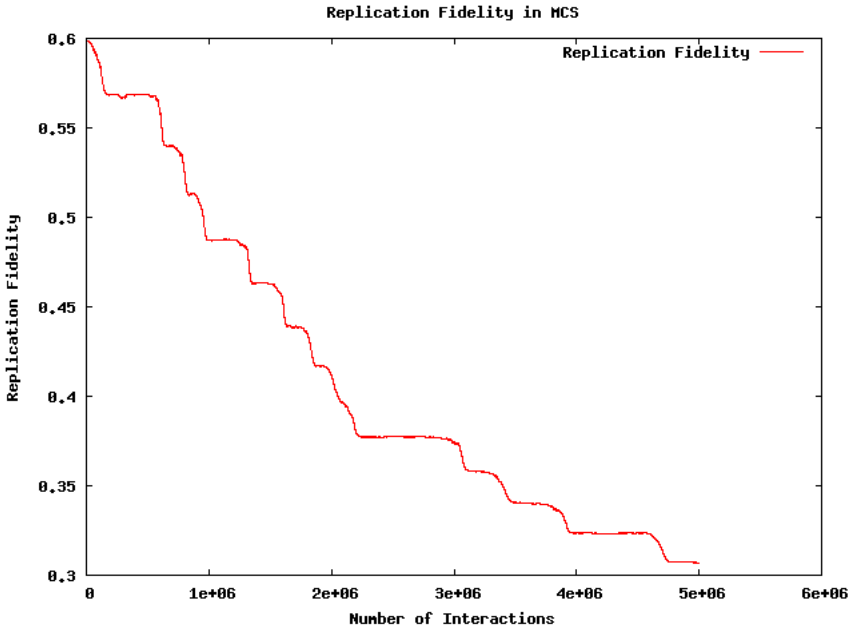
Questions, questions (but not now!)

- Why does dominant string not take over whole population?
- What is the composition of the rest of the population?
- Why does peak dominant population get progressively smaller?
- (. . . obviously there is some stuff that has not been explained yet!)

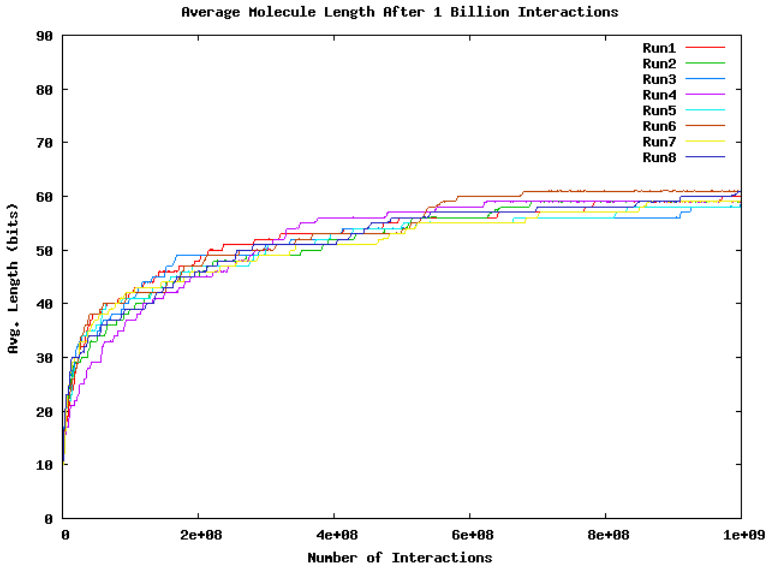
Viva la revolution?

- In this particular "flow reactor" system, *longevity* and *fecundity* are exactly, inversely, coupled, so no evolutionary scope there.
- So: that leaves *fidelity* — doesn't it?
- (Think of this as a simple "experimental control" or "sanity check".)

Well . . . maybe not!



Underlying: fidelity inversely related to length (. . . though that doesn't really explain anything!)



Summary (counter-intuition?)

- Only difference in "intrinsic" fitness of the different replicator species is in "fidelity" - and this shows a progressive, quasi-deterministic, *decay*.
- Along with this goes reducing concentration of dominant species (increased mutational load) and consequently reducing fecundity (albeit with exactly inversely increasing longevity).
- Long term outcome is total distintegration of the original organisation (progressive – no "threshold" effect).
- But this is happens through a sequence of "short term" events, each showing perfectly "darwinian" selection!?

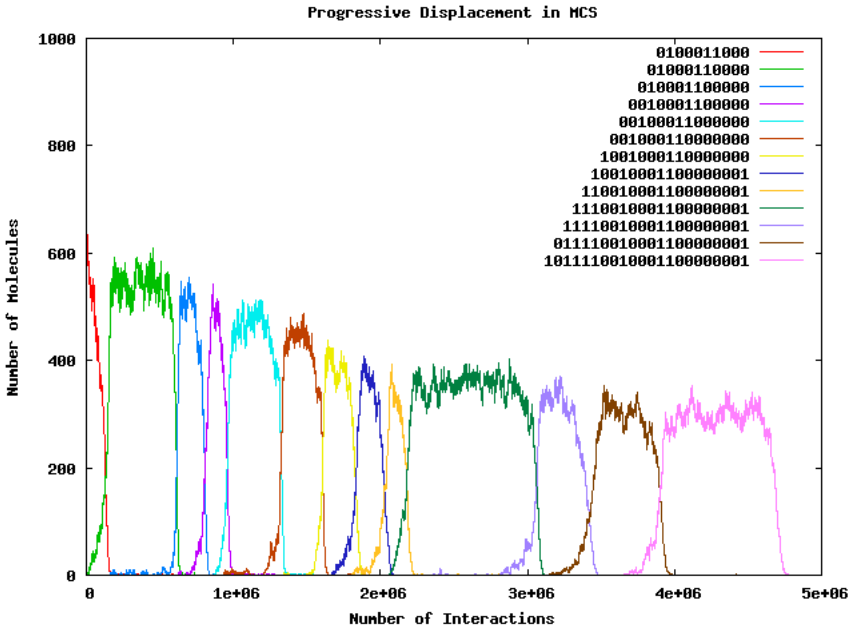
So what's really going on here?

- Enzymatic "binding rule" is "exact substring match" (Aaahhhh . . .)
- So a "super-string" will immediately parasitise any host sub-string which was previously dominant (think "hyperline" rather than "hypercycle"!); and will quickly displace it completely.
- All the "selectional" events in this particular model are of this nature: the huge "parasitic" gain easily outweighs each slight, incremental, decrement in fidelity (reducing intrinsic fitness).
- Playing games, *not* climbing mountains (improbable or otherwise!).

So what's really going on here? (Aside)

- Bimolecular, "self-catalysed", replication has hyperbolic growth rate.
- Implies density-dependent selection with positive feedback.
- Result is "survival of the common": invasion is extremely difficult - even by rivals with much higher intrinsic fitness.
- *Very* different from classical "auto-replication" (mediated by an externally buffered replicase) with exponential growth rate and yielding straightforward Darwinian selection.
- But that's a different story . . .

What I didn't show earlier



Conclusion (?): so what?

- "Yes, it's a little counter-intuitive . . .
- . . . but it's really just a very *very* contrived and peculiar toy system, with no wider ramifications!"

Conclusion (preferred!):

I may not have gone where I intended to go, but I think I have ended up where I needed to be. — Dirk Gently

- At the very least, it underlines that the Dawkins' slogan ("Longevity, Fecundity, Fidelity") is wildly over-simplistic.
- We suggest that it was worthwhile to isolate and characterise this phenomenon clearly *before* adding additional complications.
- But best of all: it immediately offers *a simple candidate problem for solution by protocell level selection.*
- So stay tuned!

Related Online Resources

- Presentation slides:
  - `http://www.eeng.dcu.ie/~alife/talks/morph-comp-2007/`
- DCU Alife Laboratory:
  - `http://www.eeng.dcu.ie/~alife/`
- Research Institute for Networks and Communications Engineering (RINCE):
  - `http://www.rince.ie/`

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