Bio-inspired circuit architectures
- The Embryonics Approach -

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Need?

- Self-replication to efficiently mass produce
- Self-repair to achieve high fault tolerance rate (e.g. against production faults)

How to achieve?

Study nature!

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- Organism level:
  multiple coorperating cells, each containing the complete DNA but only executes a tiny part of it
- Cellular level:
  consists of 'molecular' elements which produce the proteins needed for survial

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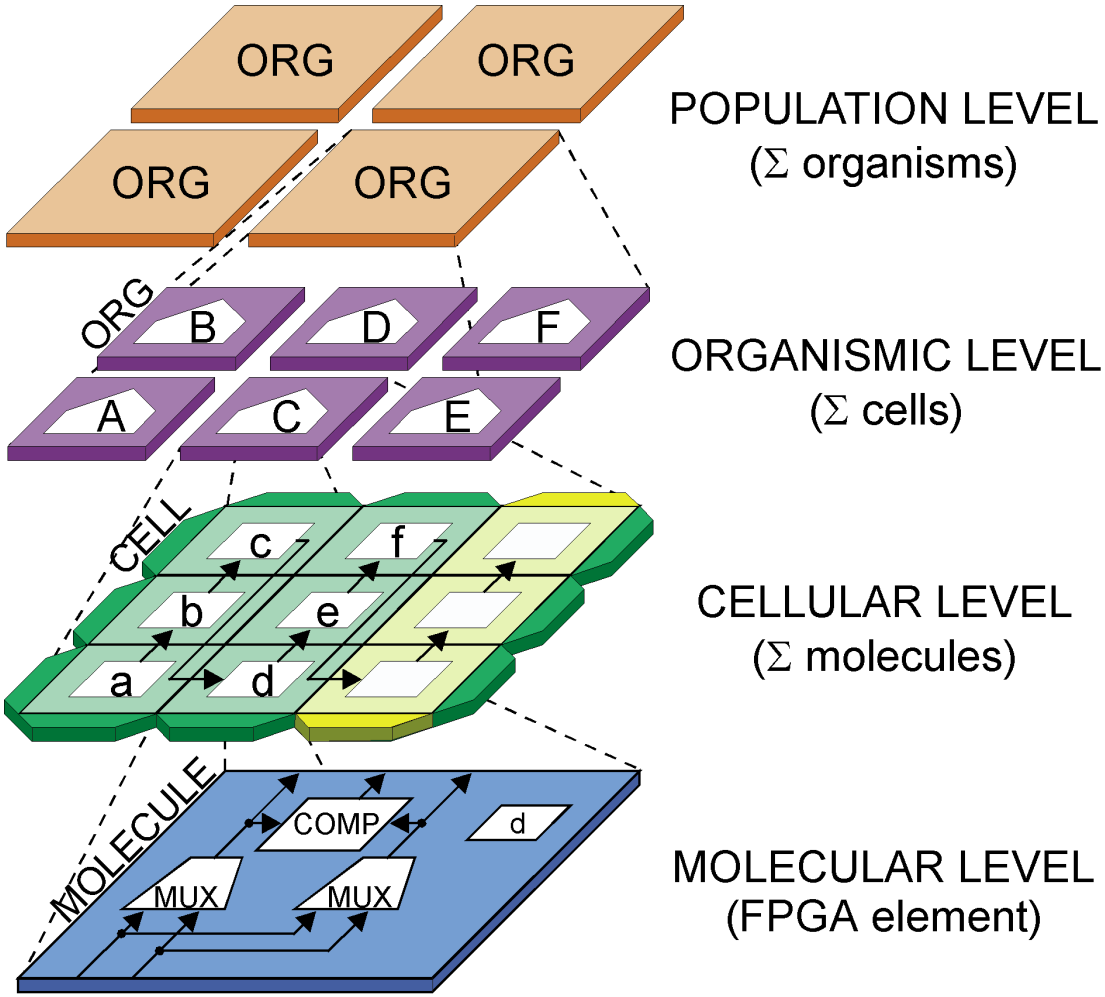
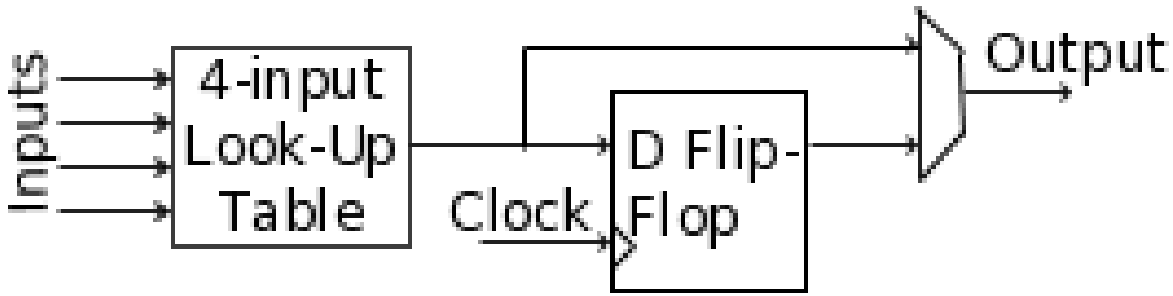
- consist of a finite number of cells, each belonging to certain group of 'specialists'
- are build, starting with one cell and using cellular division to construct new cells as copies of the original
- most cells have a unique function that characterizes them, but some don't and can virtually become anything
  (nature's void pointers)



http://www-users.york.ac.uk/ gt512/Images/4Level.gif 12.01.'13 - 12:20 CET

Field **P**rogrammable **G**ate **A**rray :



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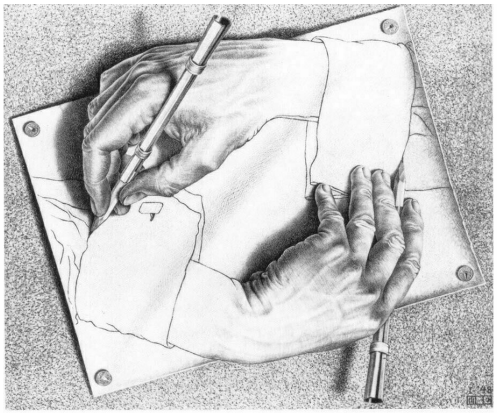
[1] http://upload.wikimedia.org/commons/6/6b/Logic_block2.svg 26.01.'13 - 12:31 CET



- Self Replication of organisms using 'cellular division'
- Properties of cells:
  - each cell contains the whole program (genome)
  - each cell knows it's position inside the organism
  - only executes part of the genome determined by it's position
  - coordinates of new cells achieved through cycling (modulo)

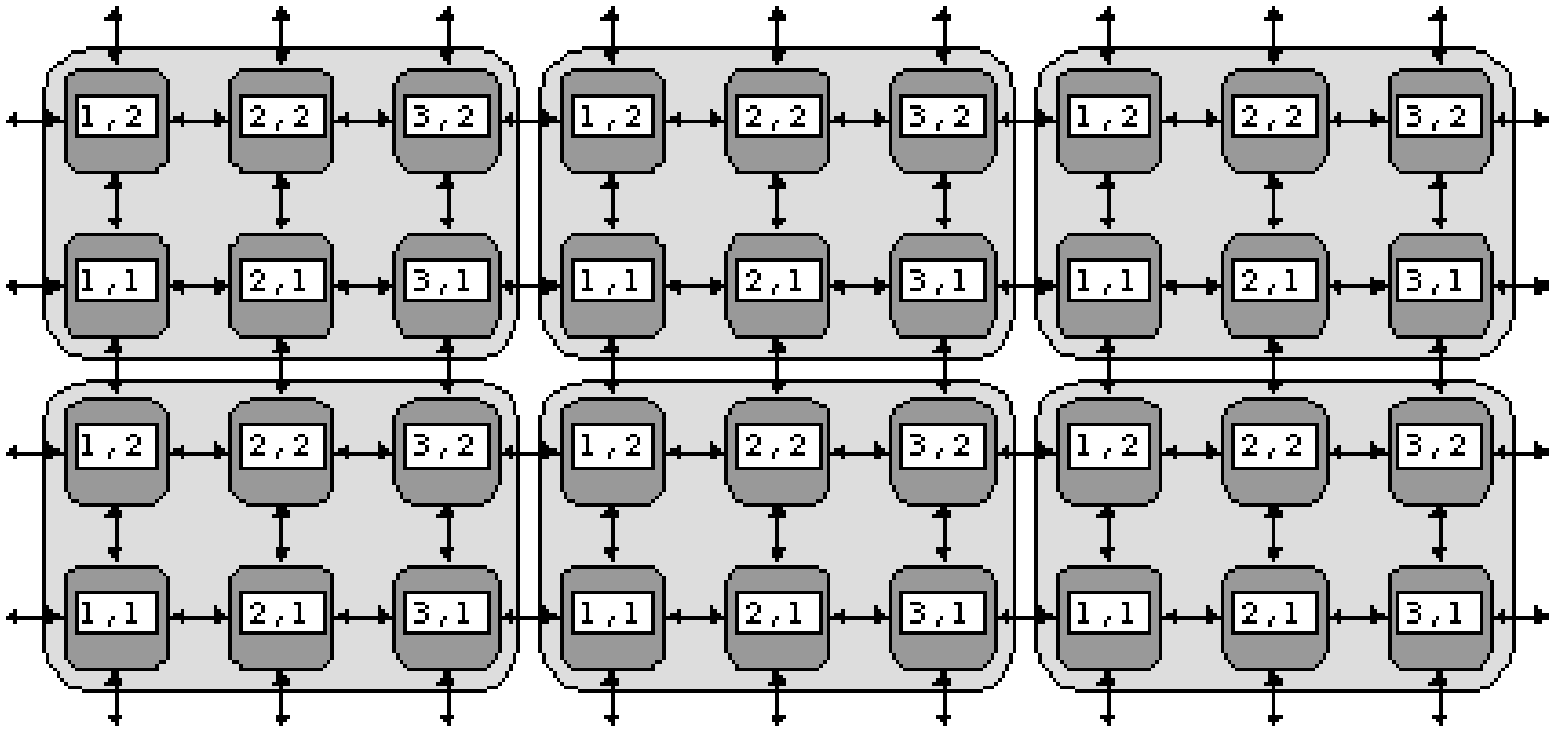


Figure 2-6: Multiple copies of the organism through coordinate cycling.

http://lslwww.epfl.ch/pages/embryonics/thesis/Thesis-11.gif 12.01.'13 - 12:27 CET

How to realize 'cellular division', which in our case means, copying the program of one cell into others?

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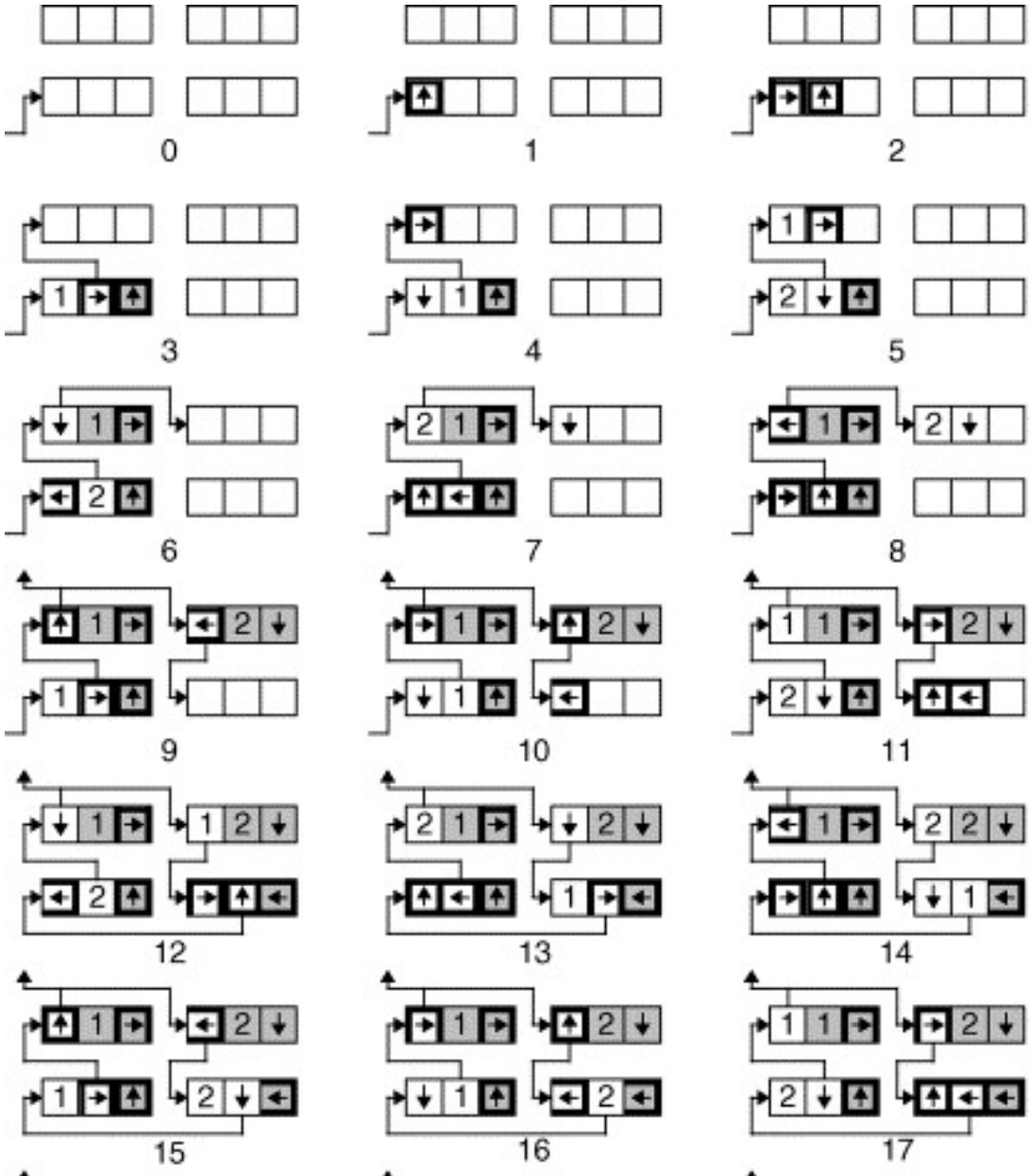
- the sum the functions of the molecules make up the cell and the specific part of the overall genome this cell executes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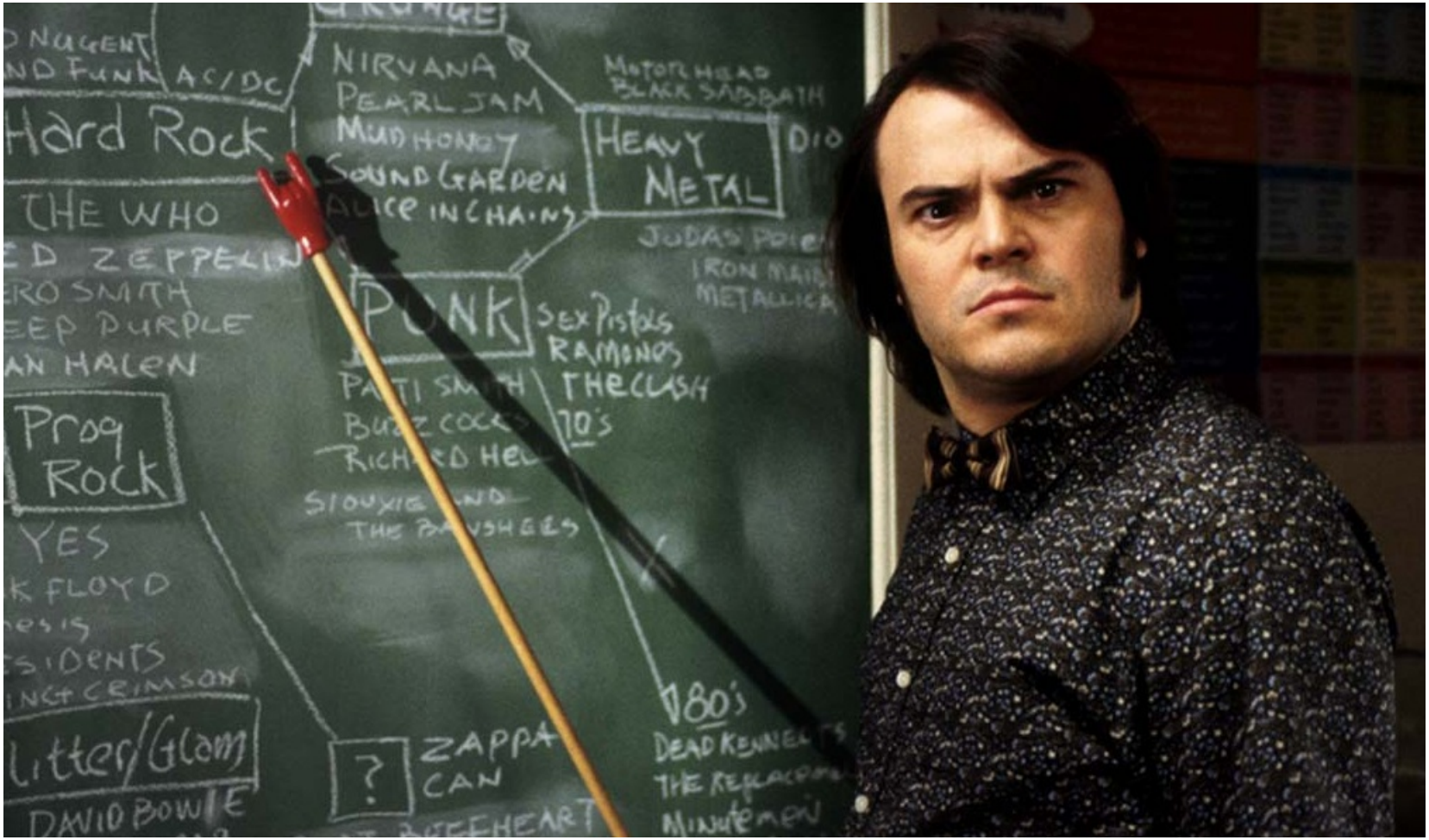
What we demand of self-repair:

- on-line repair mechanism, so we don't have to 'shutdown' the system
- no centralized control mechanism, all should be handled as local as possible
- self-repair on as much levels as possible (population, organism, cell and molecule)

But how?!

By **not** using self-repair!



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Self-Repair for organisms:

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for free

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  (to reduce replacement complexity)
- 'scaring the grid' triggers recomputation of all of the cells coord's, and the state of the now dead cells need to be recovered/copied

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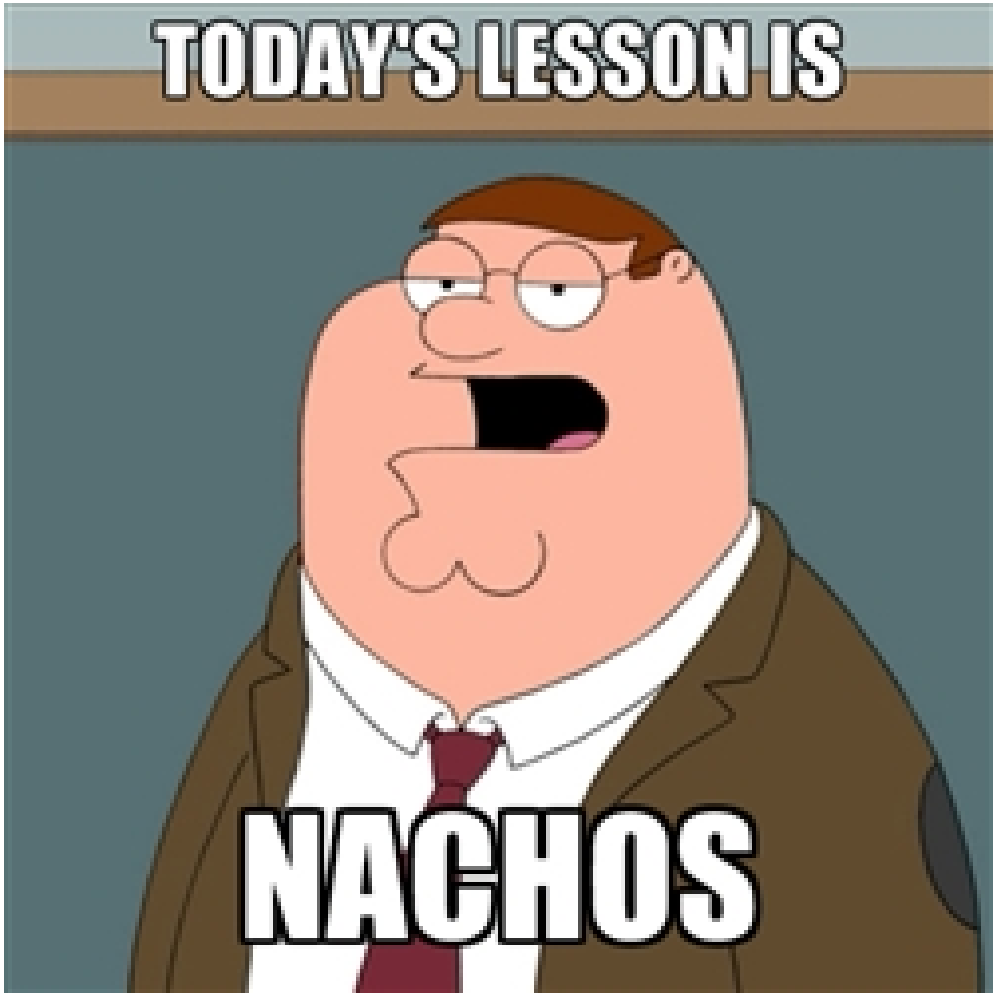
- Upside:
  can program molecules, which means we can control (program!) the level of fault tolerance/robustness of our system
- Mechanism:
  shift content of dead molecule to it's righthand neighbour and his content to his right hand neighbour, etc. 'till spare molecule is reached



http://cdn.memegenerator.net/instances/250x250/32624089.jpg - 20.01.'13 - 17:05 CET

Self-Repair:

- no 'repair', instead use spare elements
- no centralized control mechanism, all done local

- on-line self repair means:
  go off-line, reconfigure, go on-line again
  (but without intervention from 'outside')

- mechanism opperates on **multiple** levels
  (molecular and cellular)

- if molecules can't be repaired, trigger cellular self repair:
  - trigger column death of cells via 'KILL' signal
  - recompute cell coordinates

Self-Replication:

- no 'replication', FGPA's need to already exist but are 'empty'
- 'molecules' and 'cells' are connected, so they can propagate data among them
- we construct the data to be propagated and therefor 'program' an amount of molecules, which then clones itself, leading to clones of cells and ultimately clones of organism
- process continues untill we run out of 'space'
- creates identical clones, no FPGA mutation yet

Main Source:

- Embryonics Approach:
- http://lslwww.epfl.ch/pages/embryonics/thesis/

Other Projects:

- Field Programmable Gate Array (FPGA) for Bio-inspired visuo-motor control systems applied to Micro-Air Vehicles
- http://www.intechopen.com/download/pdf/5965

- On-chip visual perception of motion:
  A bio-inspired connectionist model on FPGA
- www.loria.fr/ girau/Publis/NN.pdf