Visualisation and Sonification of Artificial Life Systems and Environments

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Online notes will be available online after the conference

http://www.csse.monash.edu.au/~aland/TALKS/ecalTutorial2005.html

username ecal2005

password 1000words

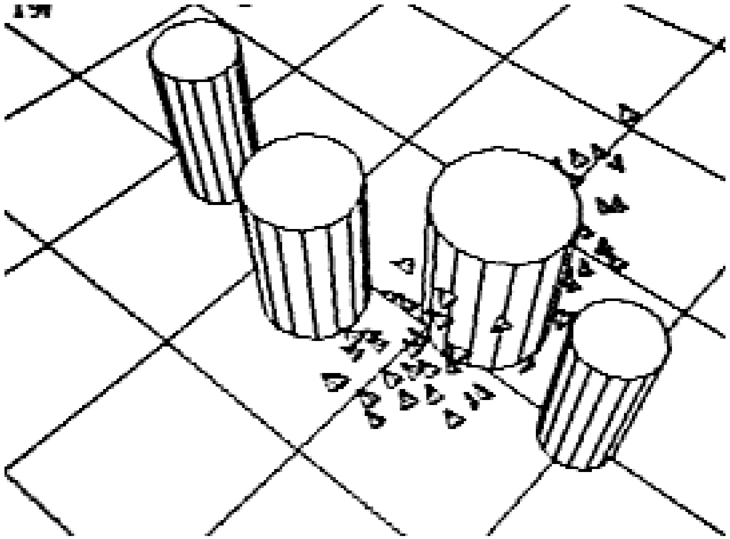
Artificial Life represents in-silico the universe’s most complex phenomena.

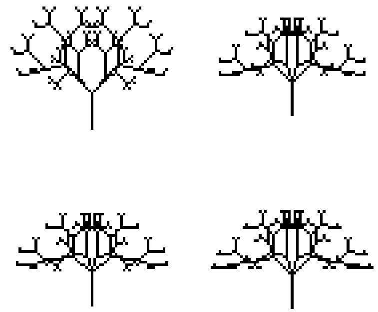
How can careful use of design strategies permit us to clarify explanations and representations of our simulations?

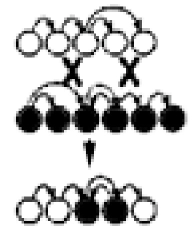
1	Visualisation	utilise the visual sense
2	Sonification	utilise the aural sense
3	Interpretation	culture and cognition
4	Prose	utilise written language (not treated in this tutorial)

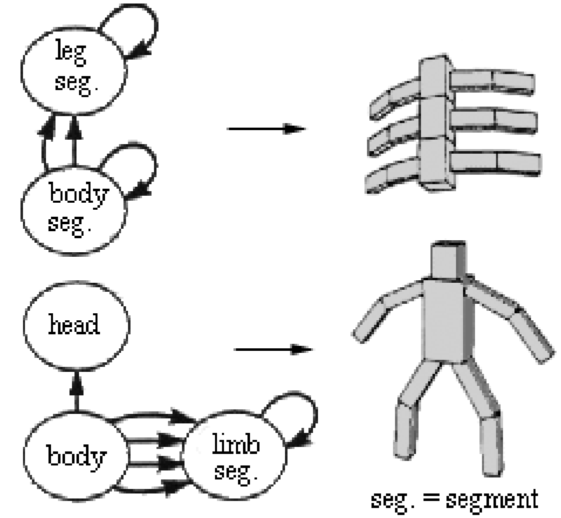
Speakers will present and discuss a selection of examples from the artificial life literature and from their own research.

To cater for a wide audience, sections ranging from introductory material to more advanced ideas will be presented... please stop us if we go to quickly or slowly.





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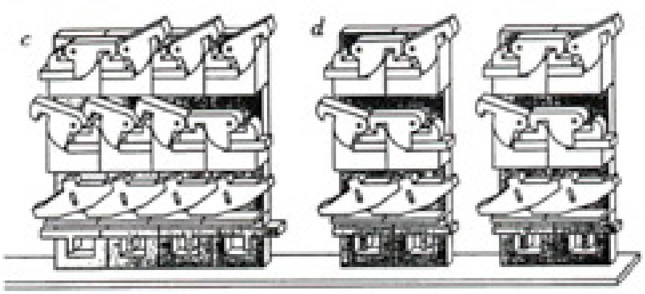
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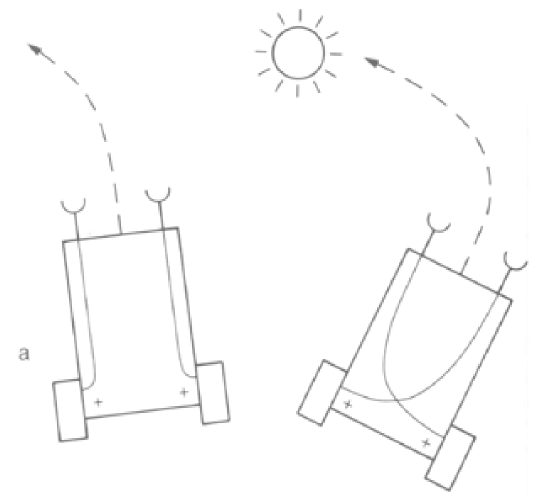
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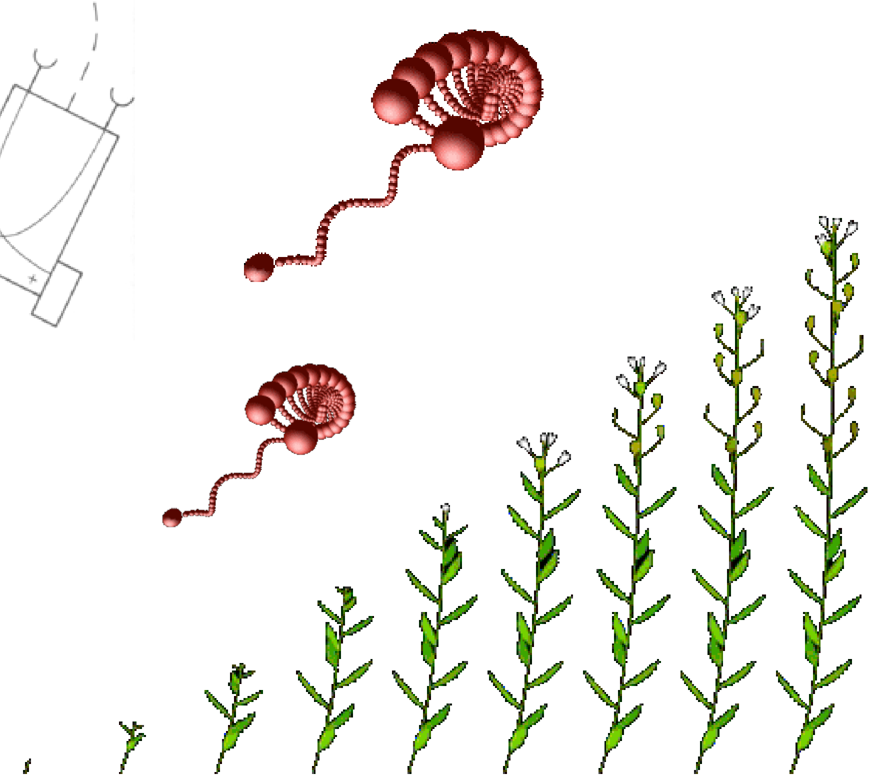
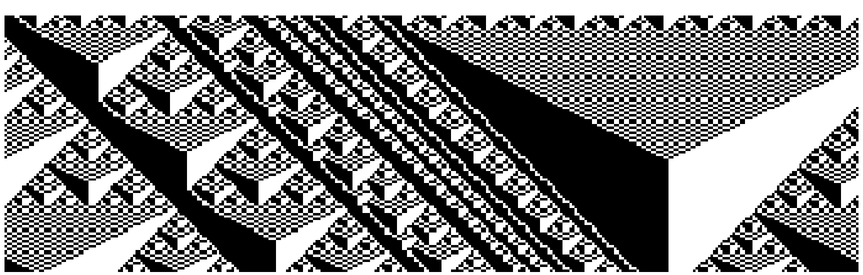




Some common Artificial Life systems

Genetic Algorithms
Cellular Automata
Artificial Chemistries
Software Agents and Ecosystems

Of course the exact visualisation requirements will vary.
“Who will see my visualisation?”

Me? Students? Colleagues? Passers-by? Computer Scientists? Biologists? Historians? Philosophers? People who don’t share my first language? Tired paper reviewers? The media? People with money to offer? Experts? Beginners? Lay-people? Engineers? Museum visitors?

“What will my *audience* be looking for?”

There is no silver bullet...

Visualising Genetic Algorithms

Some common applications for visualisation

- crossover & mutation processes
- mean, best & worst fitness
- genetic & phenotypic diversity
- genealogies
- spread of an allele through a population

These are temporal phenomena.

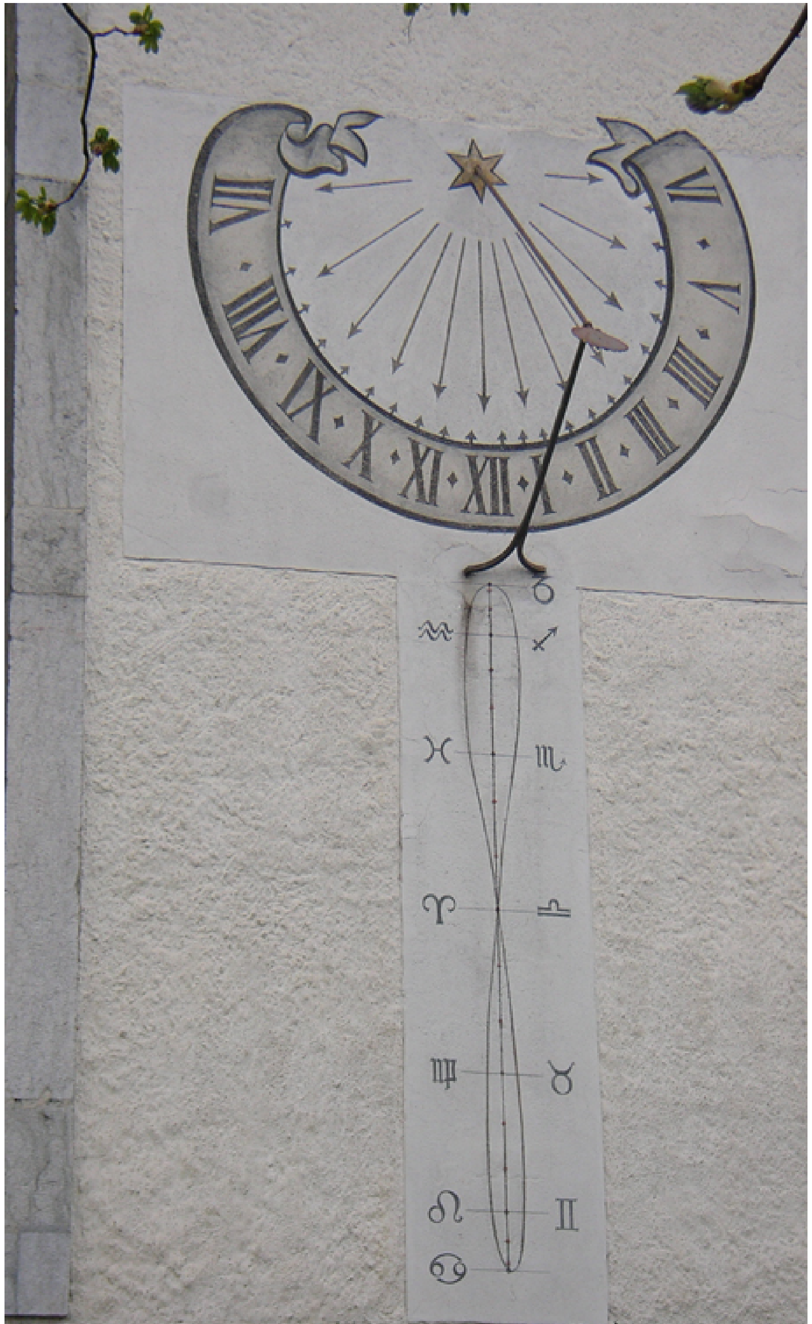
Techniques for visualising time

Preserve the temporal dimension by utilising temporal media

Armillary spheres, Museum of the History of Scientific Instruments
Geneva Switzerland

Techniques for visualising time

Map the temporal dimension to another dimension and combine it with a temporal medium

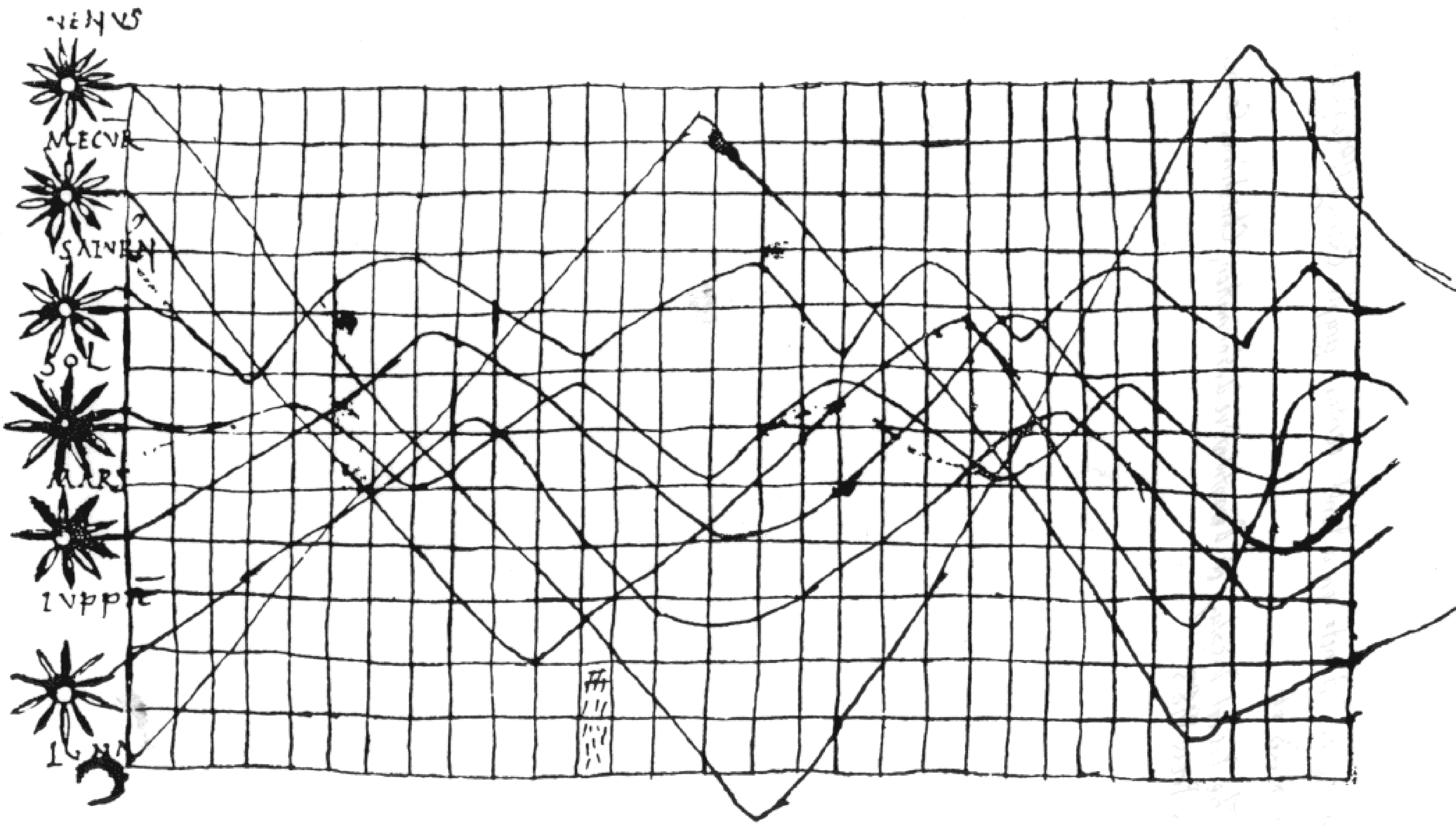


Thun solar clock, Switzerland

Bern mechanical clock, Switzerland

Techniques for visualising time

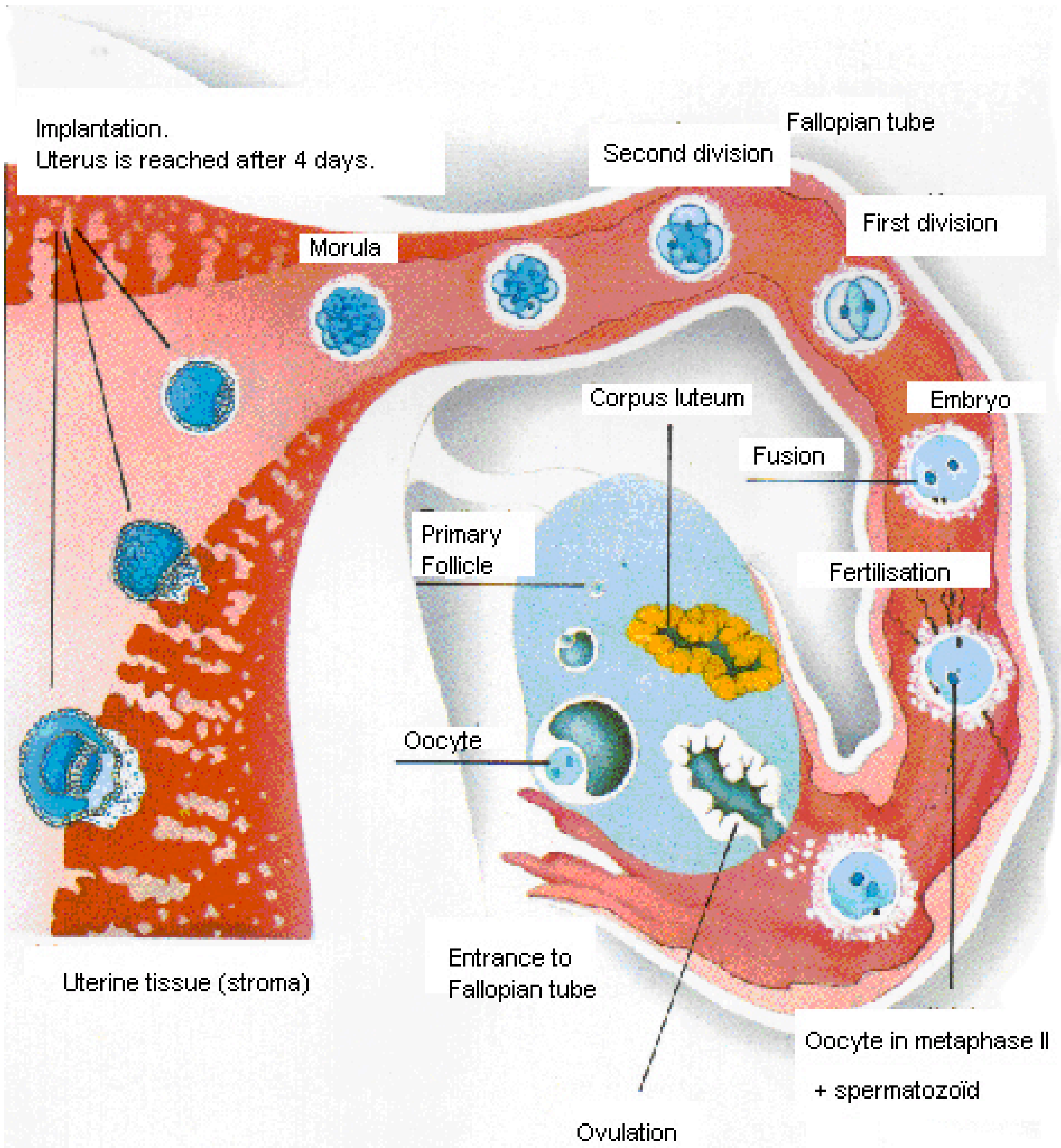
Map time to another dimension (abscissa) and use static media to plot the course of a change (ordinate)



H Gray Funkhauser, "A note on a tenth century graph", Osiris 1 (1936), 260-262,
reproduced on p.28 of E R Tufte, The Visual Display of Quantitative Information, Cheshire, CT: Graphics Press 1983

Techniques for visualising time

Employ “small multiples” to show structural development



http://www.coe.int/T/E/Legal_Affairs/Legal_co-operation/Bioethics/Activities/Human_embryo_and_foetus

Before we go any further...

1. Find a pen and a blank sheet of paper

2. Illustrate the process of (digital) genetic crossover acting on a pair of linear arrays

3. *After* you have finished, compare diagrams with your neighbours

Were the diagrams the same?

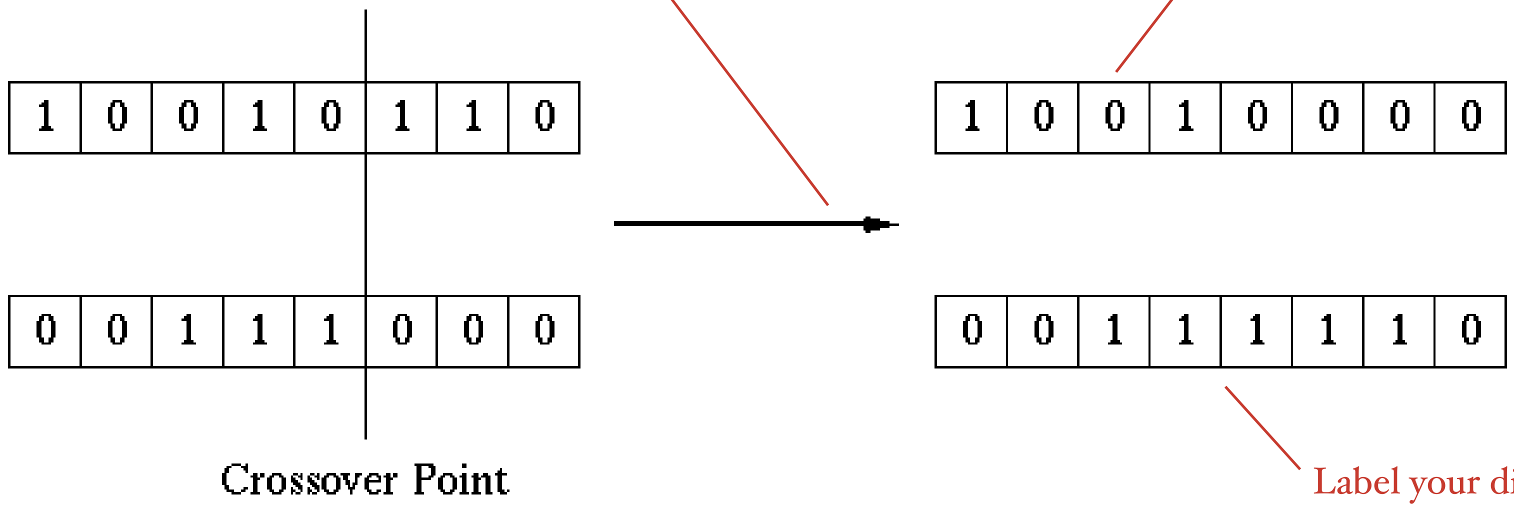
How did they differ?
Why did they differ?

Explaining crossover

Arrows clearly indicate a change over time (process) but in this case, *which* process? Label the arrow "crossover"

Label your diagram's components. E.g. "parent 1"

Highlight directly which sections of the children are derived from each parent



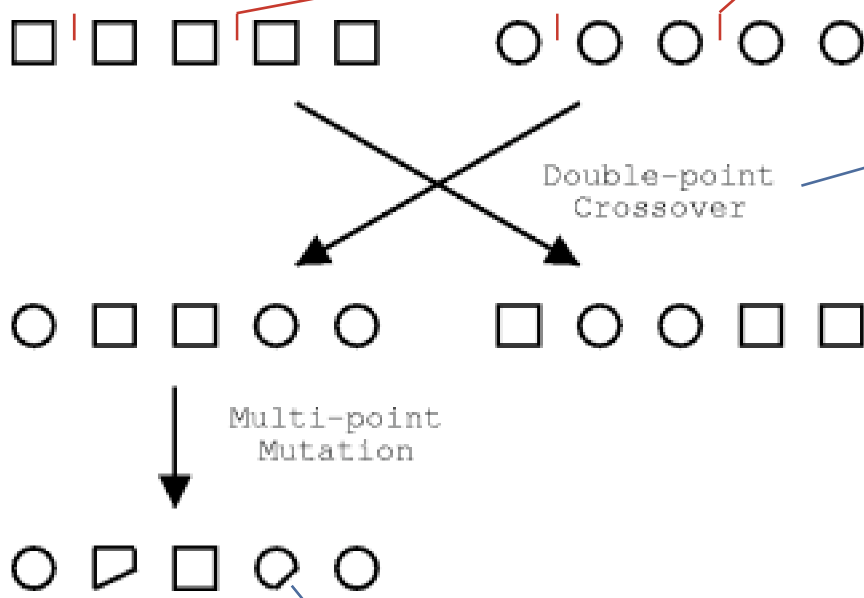
Label your diagram's components. E.g. "child 2"

Clearly mark crossover points on the parents showing correspondence between them

...it may seem obvious to you. You have no excuse for not making it equally obvious to your students!

Explaining crossover

Clearly mark and label crossover points on the parents



Processes are labelled

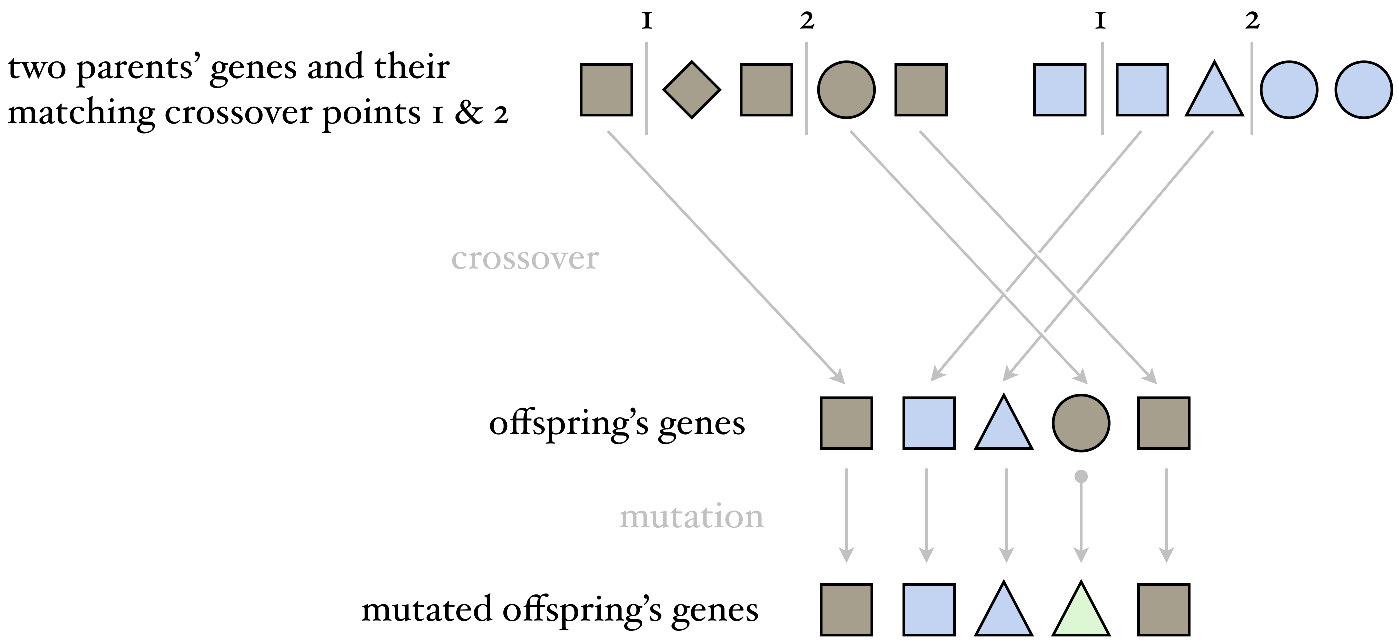
Label a diagram's components. E.g. "child 1"

Use of shape to convey gene origins

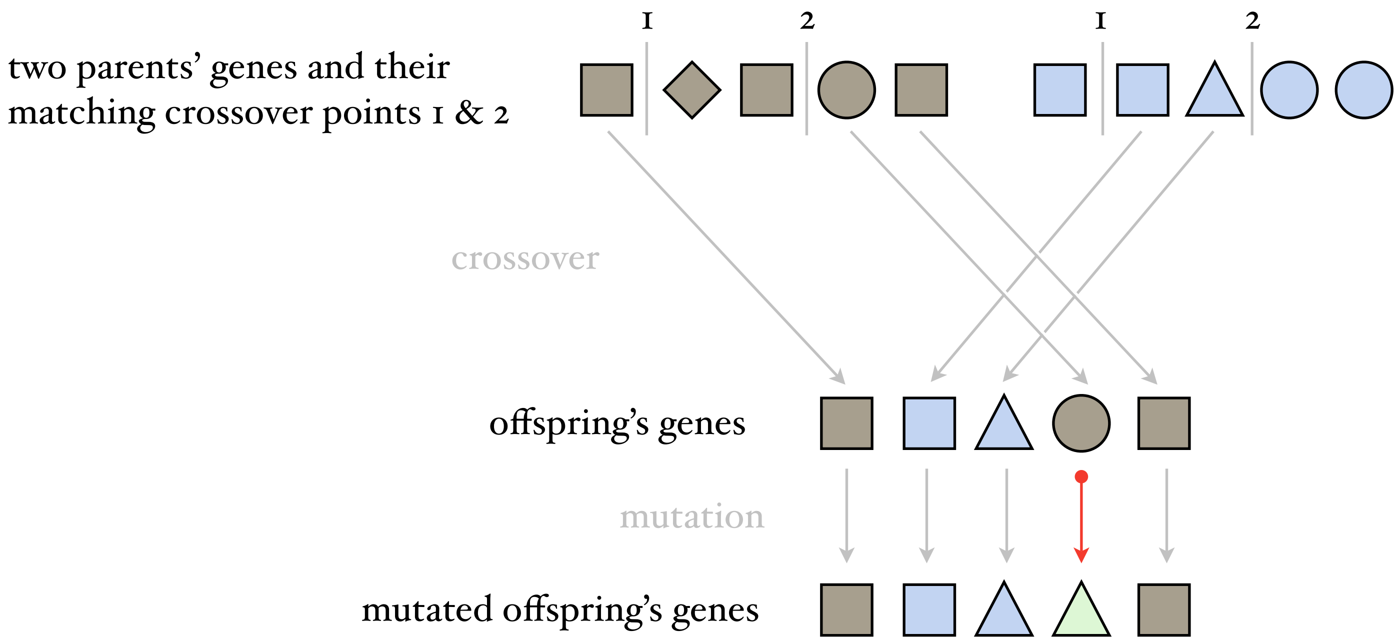
Modification of shape whilst retaining the link to the parent's gene

http://gaul.sourceforge.net/images/ga_double.png

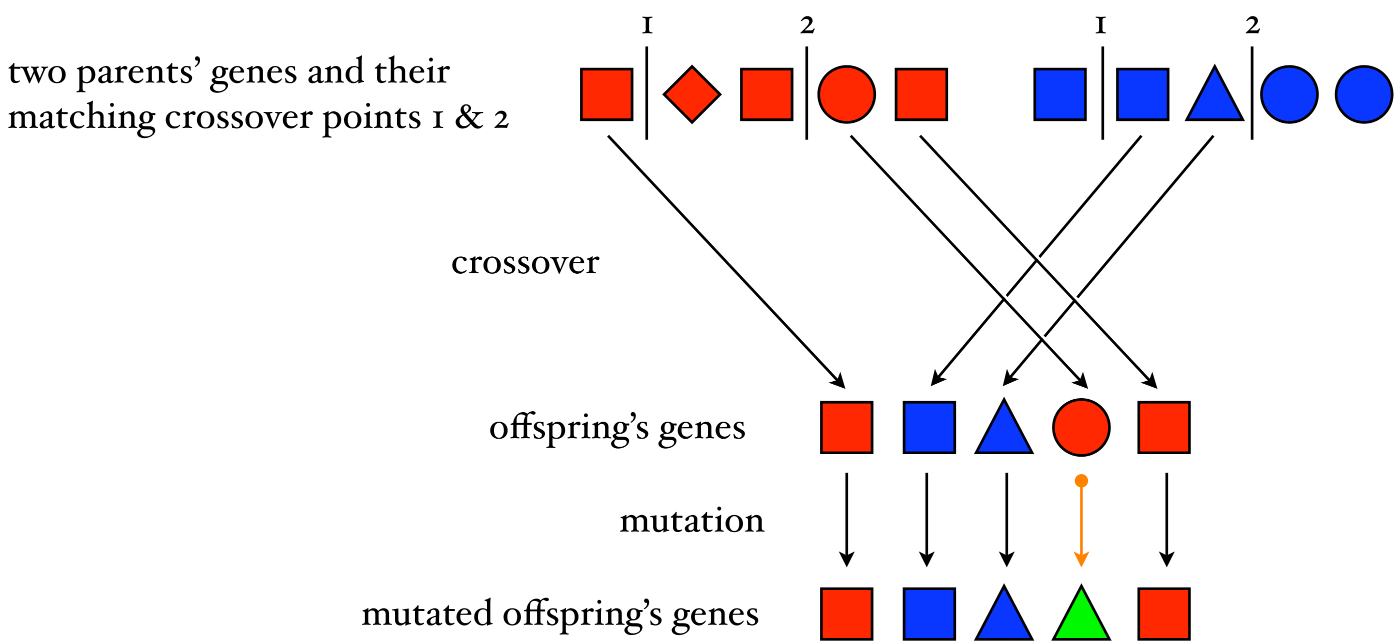
Explaining crossover



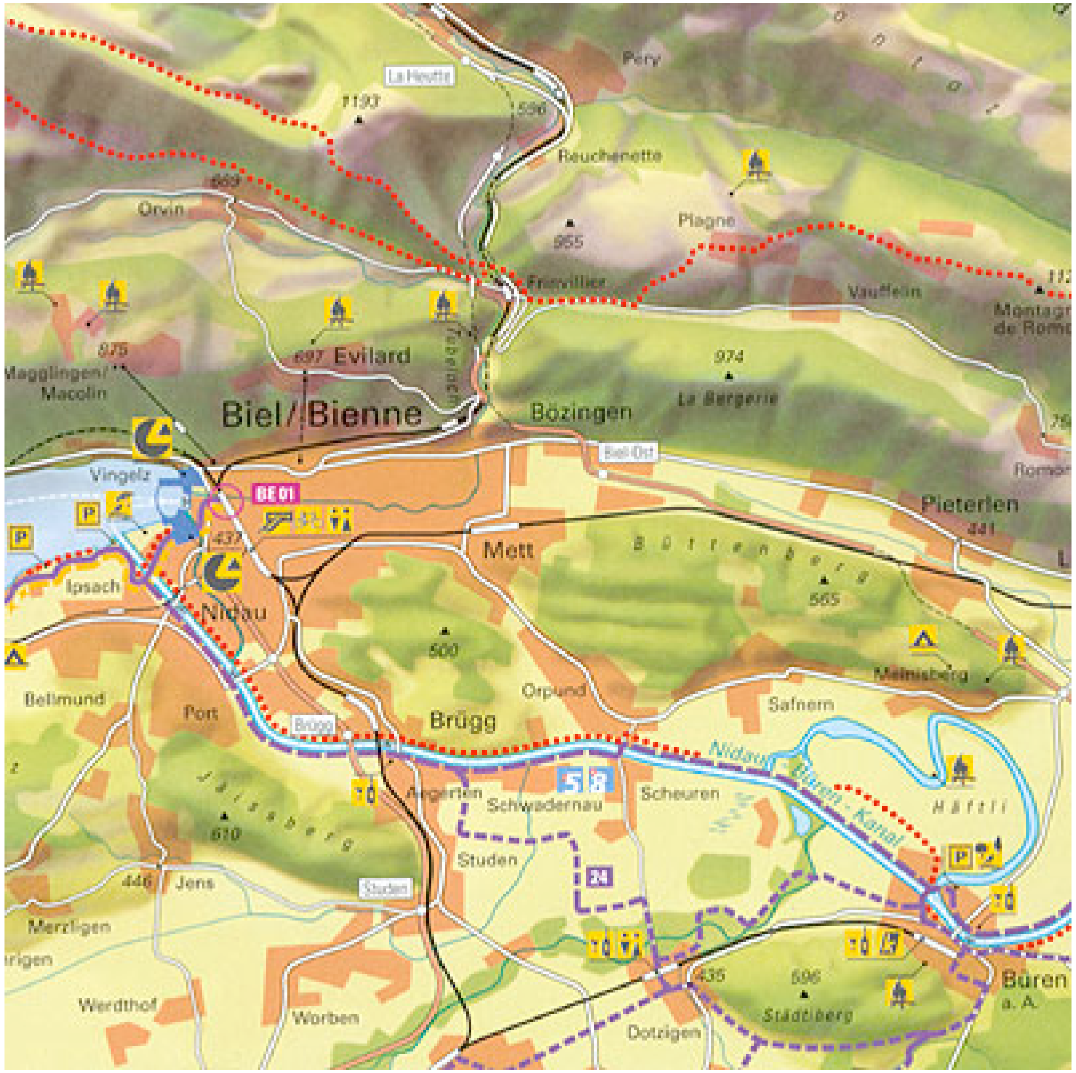
Explaining crossover



Explaining crossover

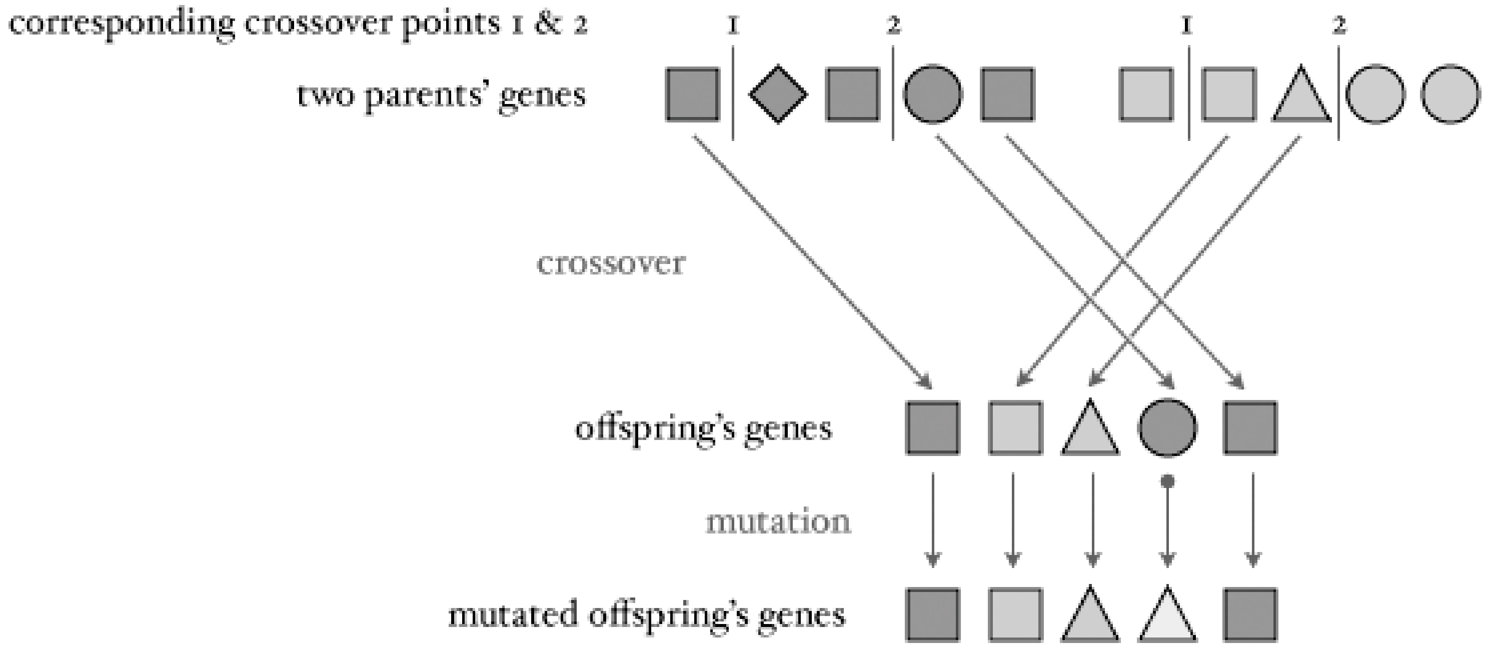


"What not to wear"



Wäger & Partner GmbH Institute of Cartography, ETH Zürich

Explaining crossover



For Jon's benefit, here's proof that my original diagram works in grey-scale

Now that you've seen some examples...

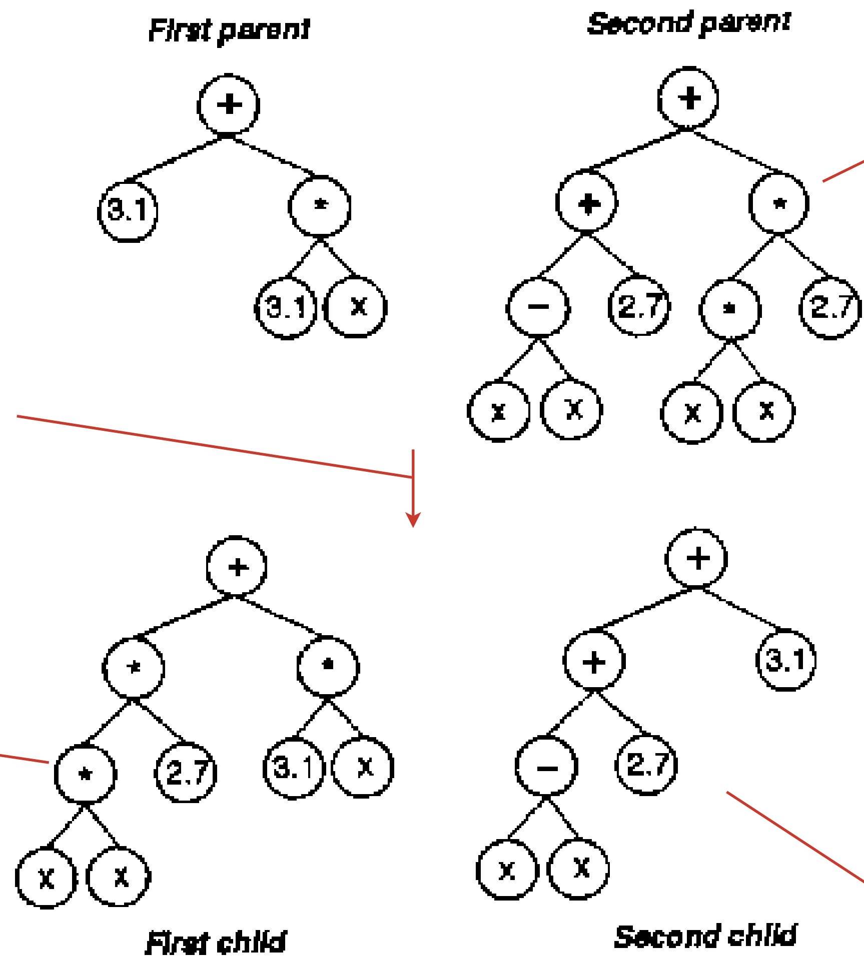
1. Take a fresh sheet of paper
2. Illustrate (digital) genetic crossover acting on a pair of hierarchical data-structures
3. *After* you have finished, compare diagrams with your neighbours

How did your neighbour do this time?

Explaining crossover

To explain crossover, highlight the crossover points, don't force the reader to work them out

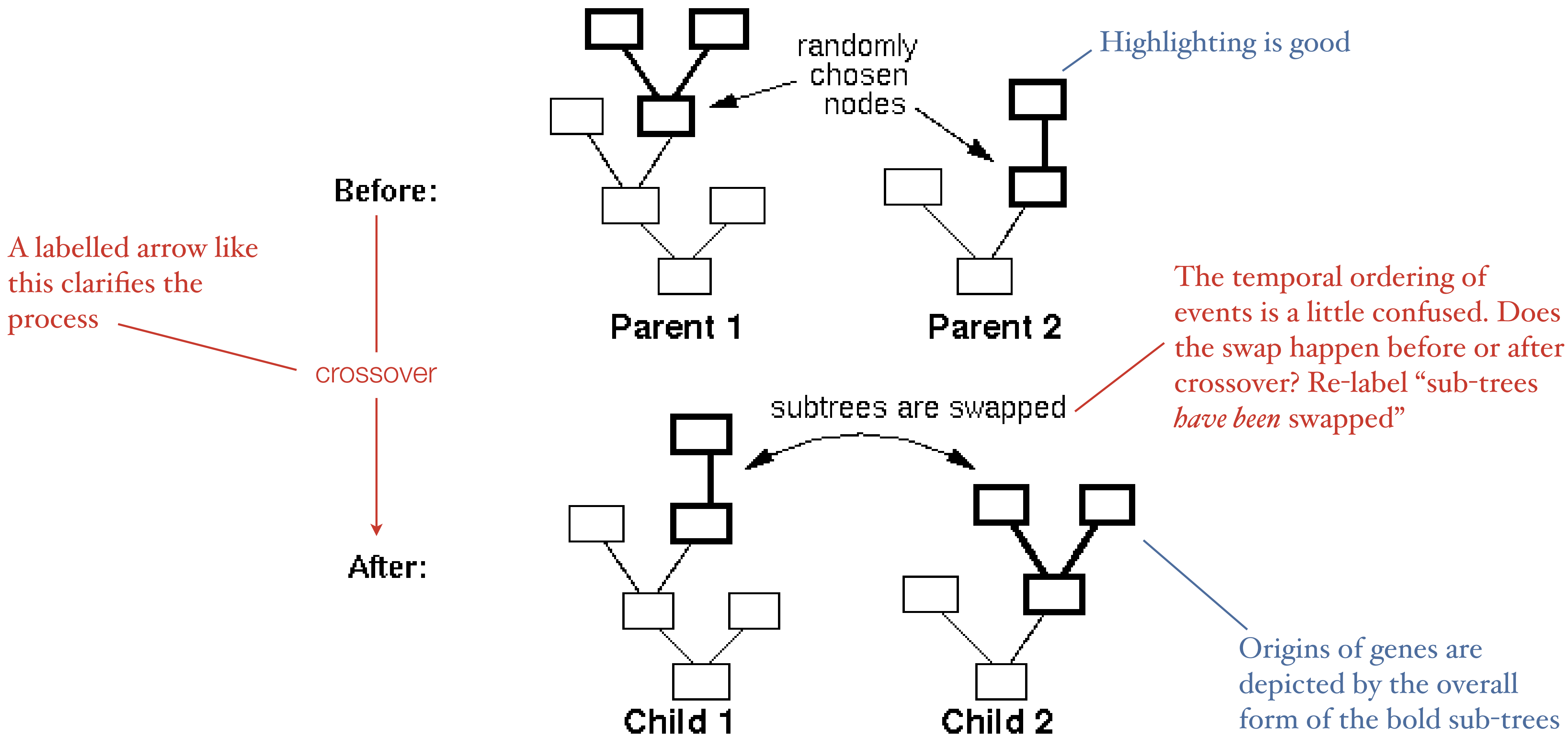
Indicate clearly *before* and *after* status with labels or an arrow. Label the arrow with the name of the process, crossover



Show clearly which sections are derived from each parent using colour, shading or shape

The presence of the second child may not help explain the process. It may confuse the issue.

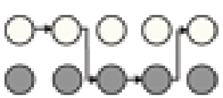
Explaining crossover



Bruce Edmonds http://jasss.soc.surrey.ac.uk/2/1/reviews/cross.gif

Explaining crossover

One arrow indicating a path from a parent to the next might be clearer



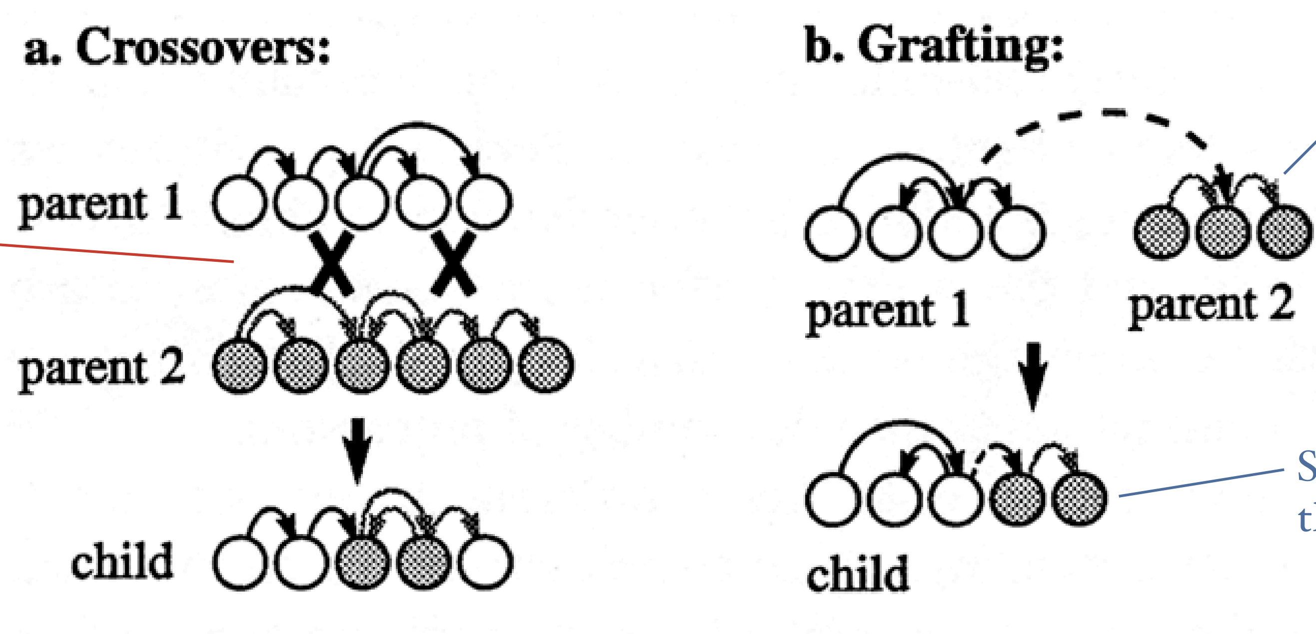


Figure 7: Two methods for mating directed graphs.

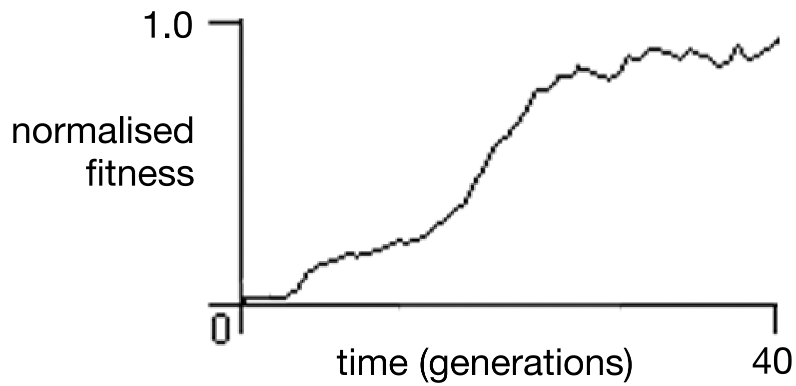
Helpful graph links of different line type

Shading clarifies the nodes' origins

Sims, Proceedings of Artificial Life IV, p35

Fitness versus time

The infamous (but sometimes helpful) fitness / time graph



Before you insert the graph into your paper, ask yourself...

"Does my graph have any interesting or unusual features?"

If not, why are you inserting it?

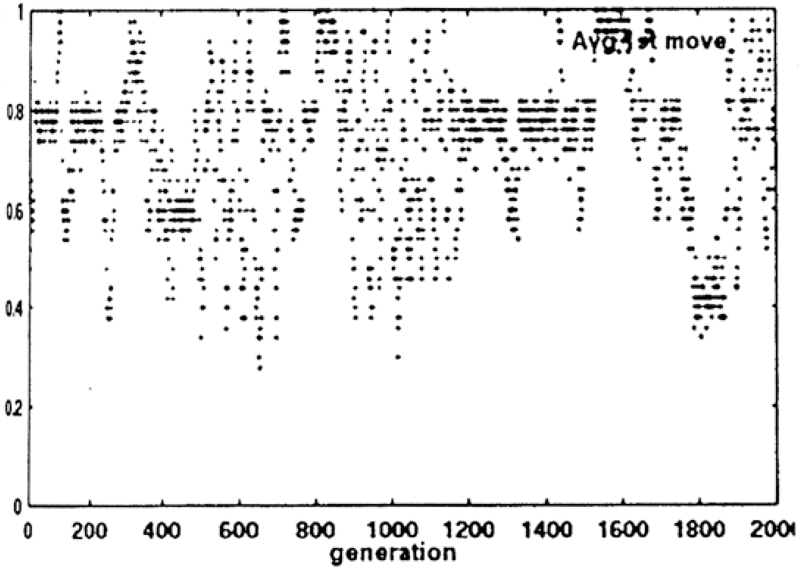


Figure 9.
Average first move.

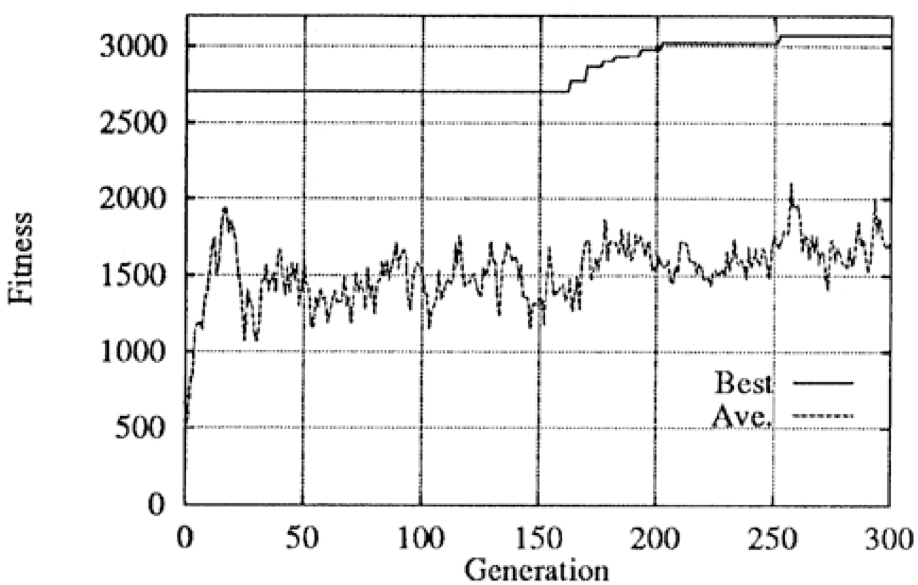


Figure 9: Evolution in binary adder

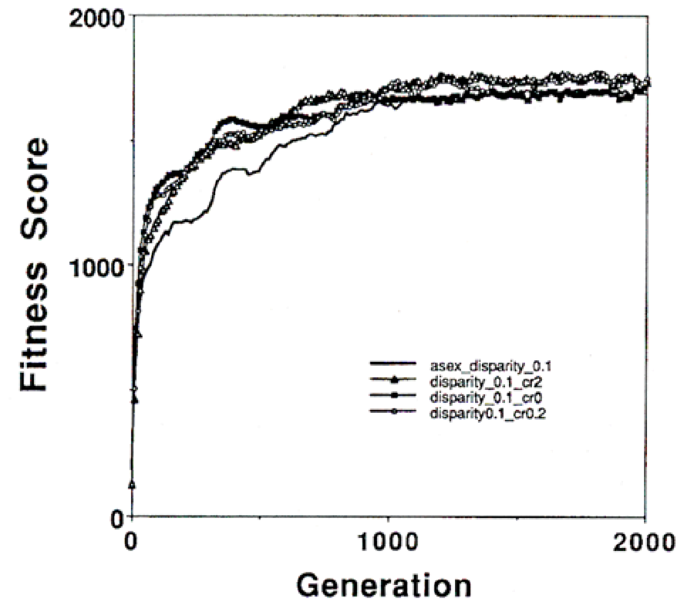


Figure 8. The results of simulations of the disparity, diploid and sexual ds-DNA GA with a mutation rate $n = 0.1$, up to the 2000th generation. Solid line, the disparity, diploid and asexual individuals; triangle, the disparity, diploid and sexual individuals with crossover (the frequency = 2.0); open circle, the disparity, diploid and sexual individuals with crossover (the frequency = 0.2); rectangle, the disparity, diploid and sexual individuals without crossover.

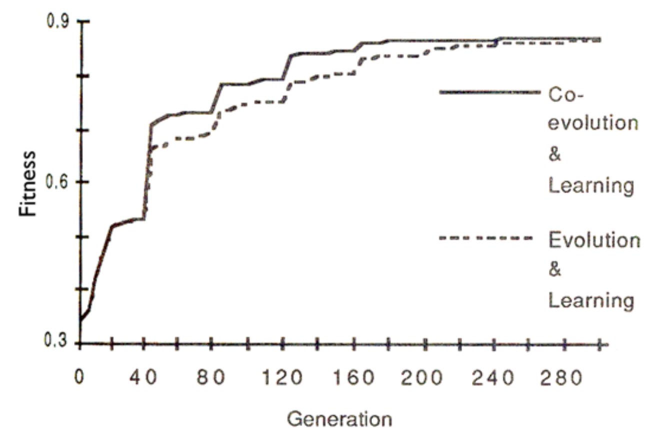


Figure 4.

Raw data plots successfully show individual data points without hiding them in averaged data

Keep axis tick marks well clear of data (point them outwards)

Keep text clear of data!

Remember to label the axes!

Reduce the weight of axis strokes to the minimum that is clearly discerned. Discard them altogether if possible.

Outliers are clearly visualised in raw data plots

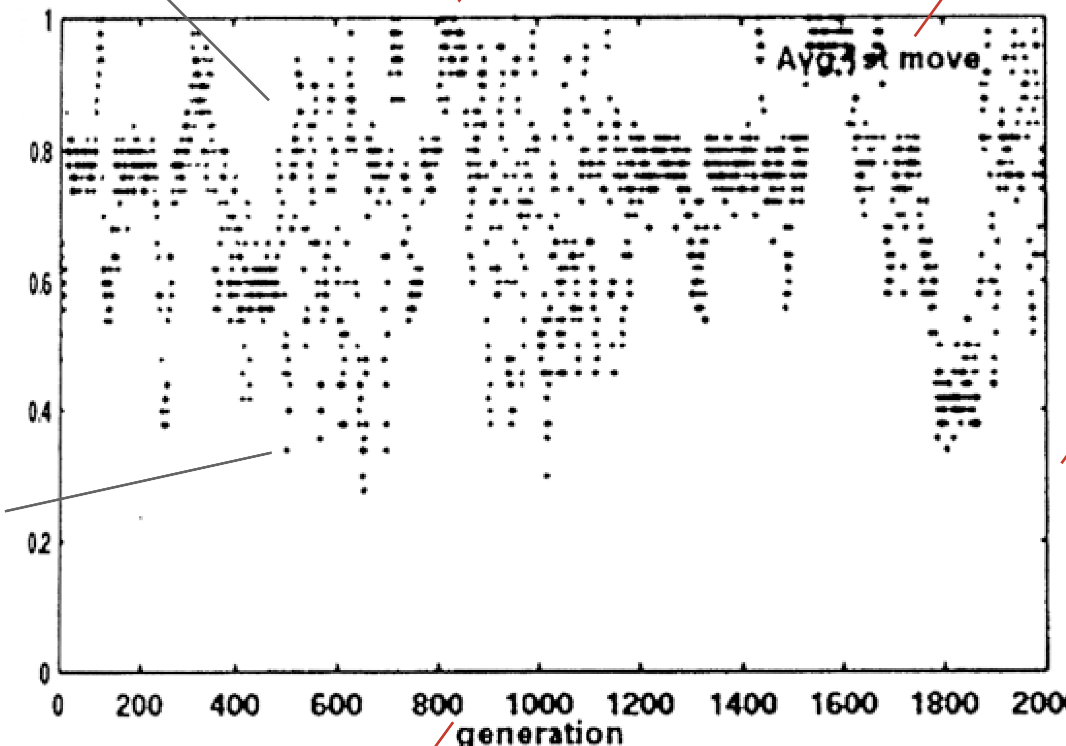


Figure 9.
Average first move.

Allow a consistent amount of space between text for clarity

Take care importing an image from one application to another

Where possible, make captions and graphs “free-standing”. When skimming, people frequently examine images and captions alone

Bankes, Proceedings of Artificial Life IV, p341

Reduce the weight of grid strokes to the bare minimum to allow the data content to dominate. If possible, remove the grid altogether

Places information where it is needed: label data lines directly instead of in a legend

Labelling data lines directly avoids the need to employ different line styles

Avoid abbreviations especially when complete labels will fit

Orient text horizontally for clarity

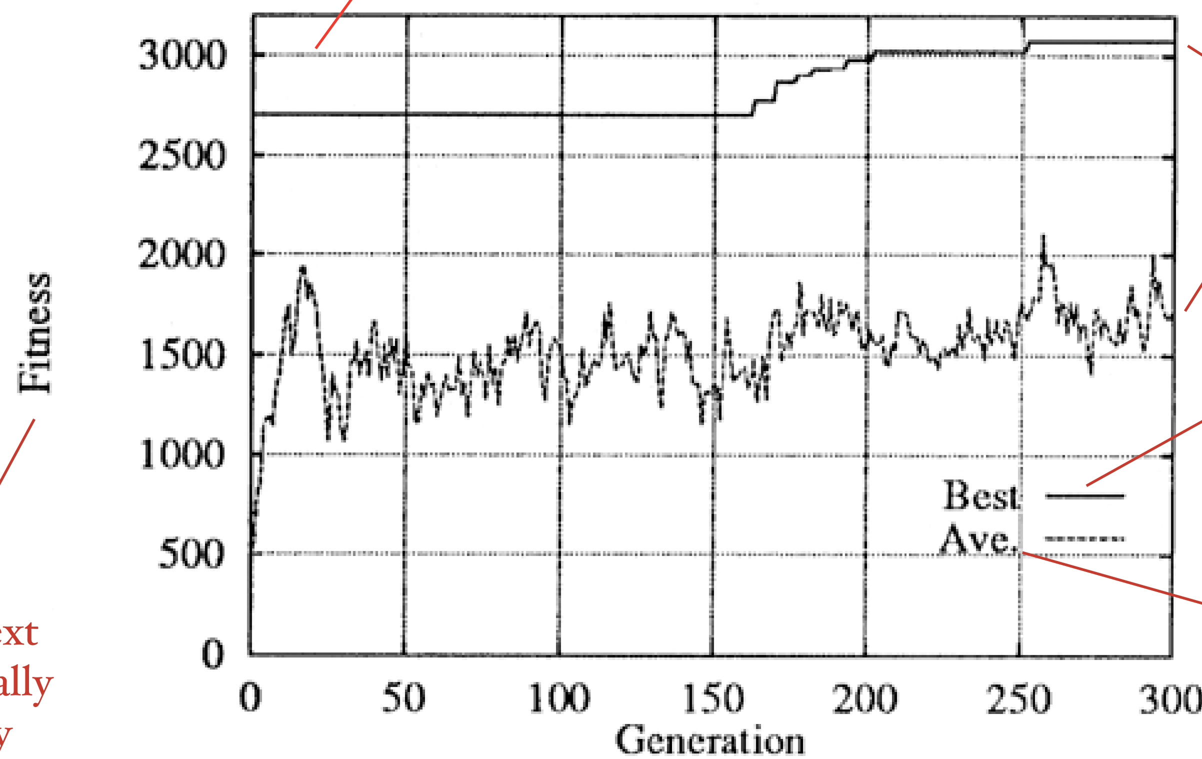


Figure 9: Evolution in binary adder

Hemmi, Proceedings of Artificial Life IV, p376

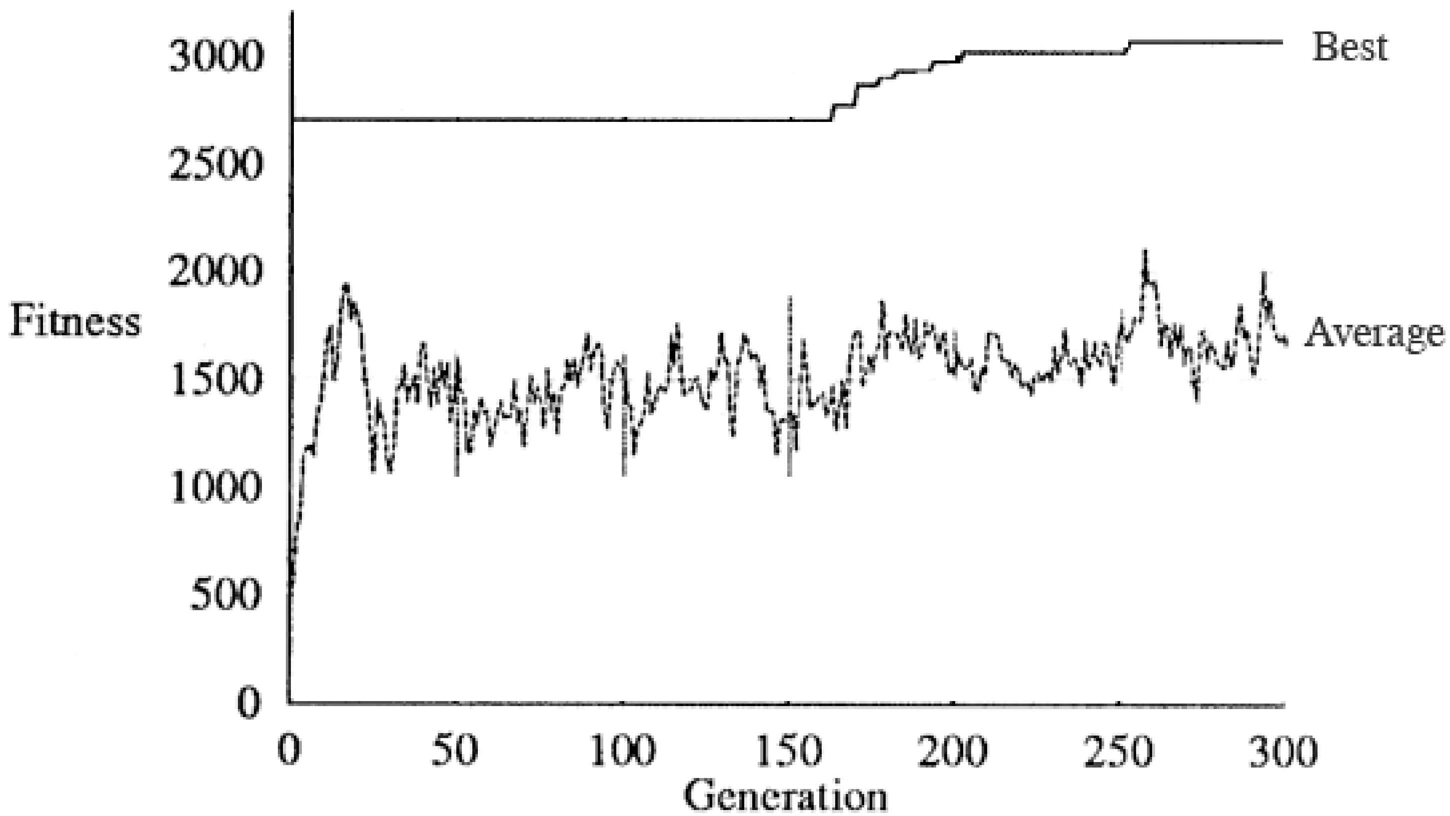
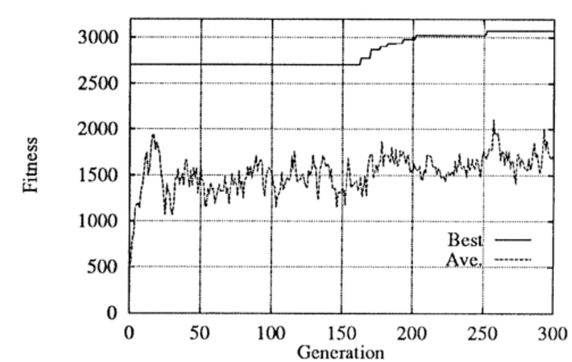
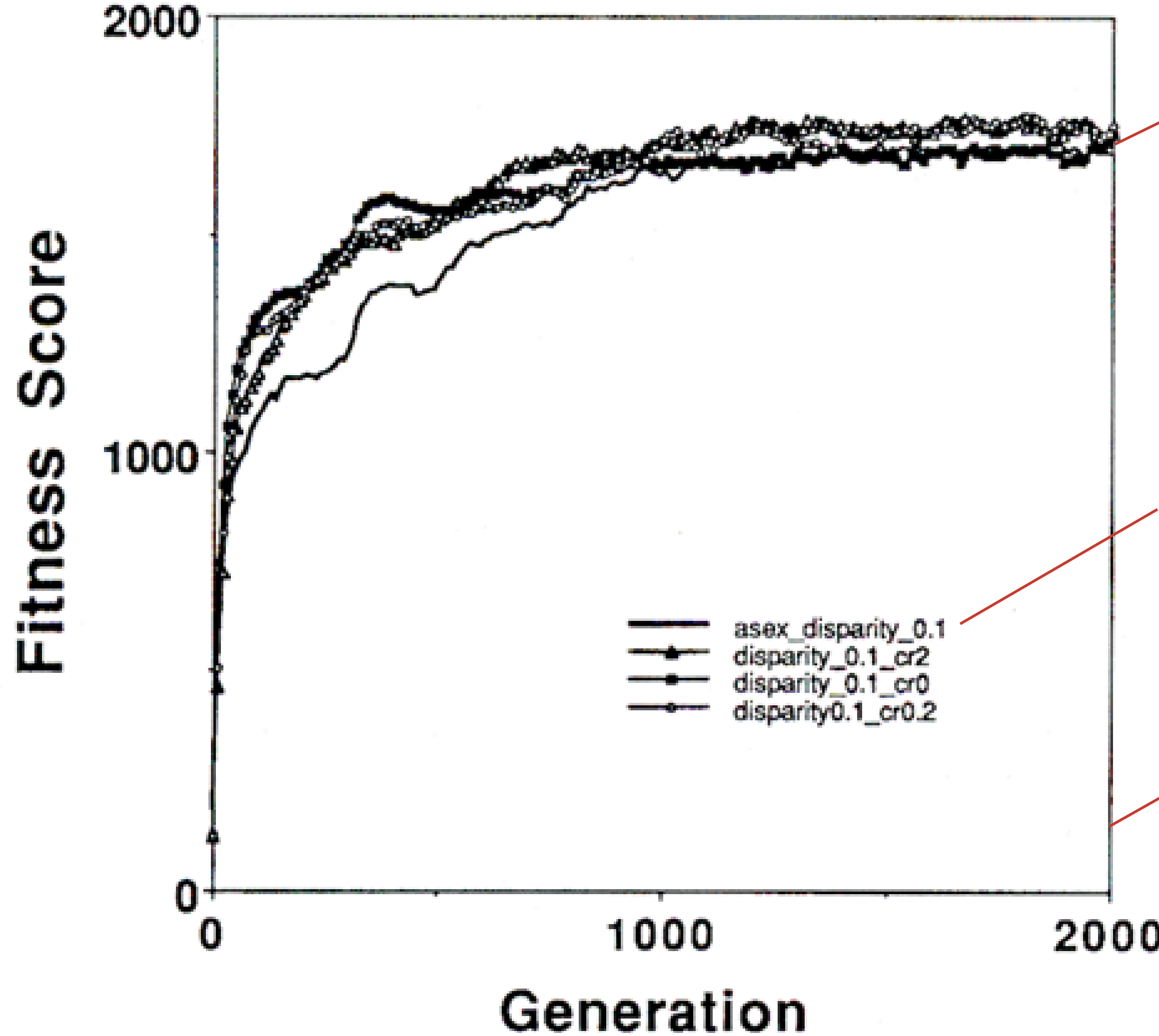


Figure 9: Evolution in binary adder

Small changes make a big difference to the graph's clarity.





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Employ data markers that are small and a scale that is large enough to clearly read the curves

Employ clear labels, not software variable names employing the "_" character. Label the curves on the graph, rather than in a legend

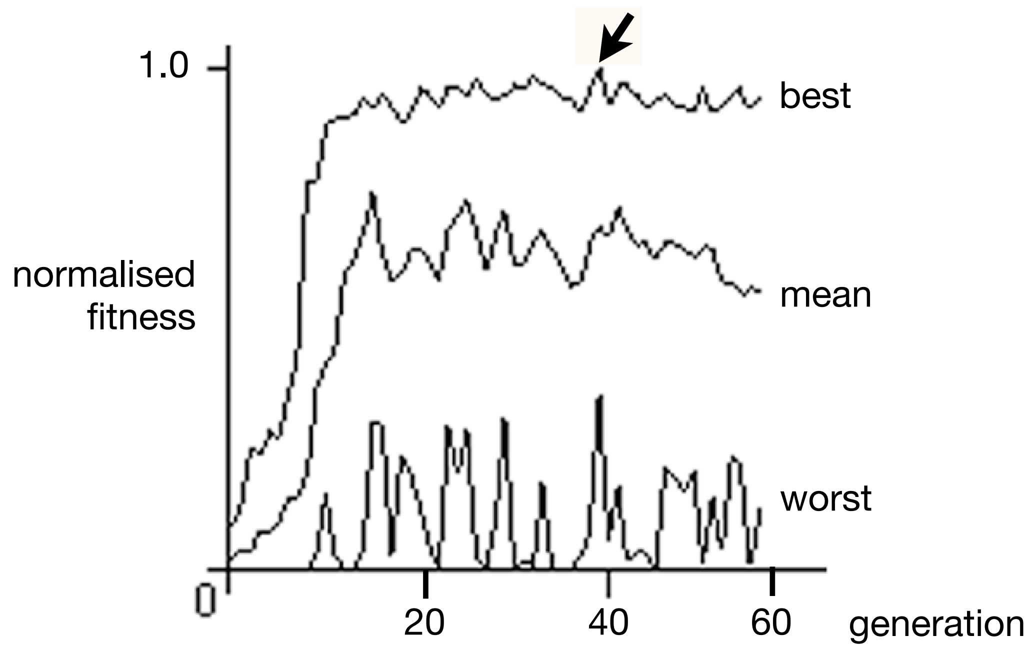
Omit unnecessary axes

If possible, place information directly on the graph in preference to in a wordy caption

Doi, Proceedings of Artificial Life IV, p364

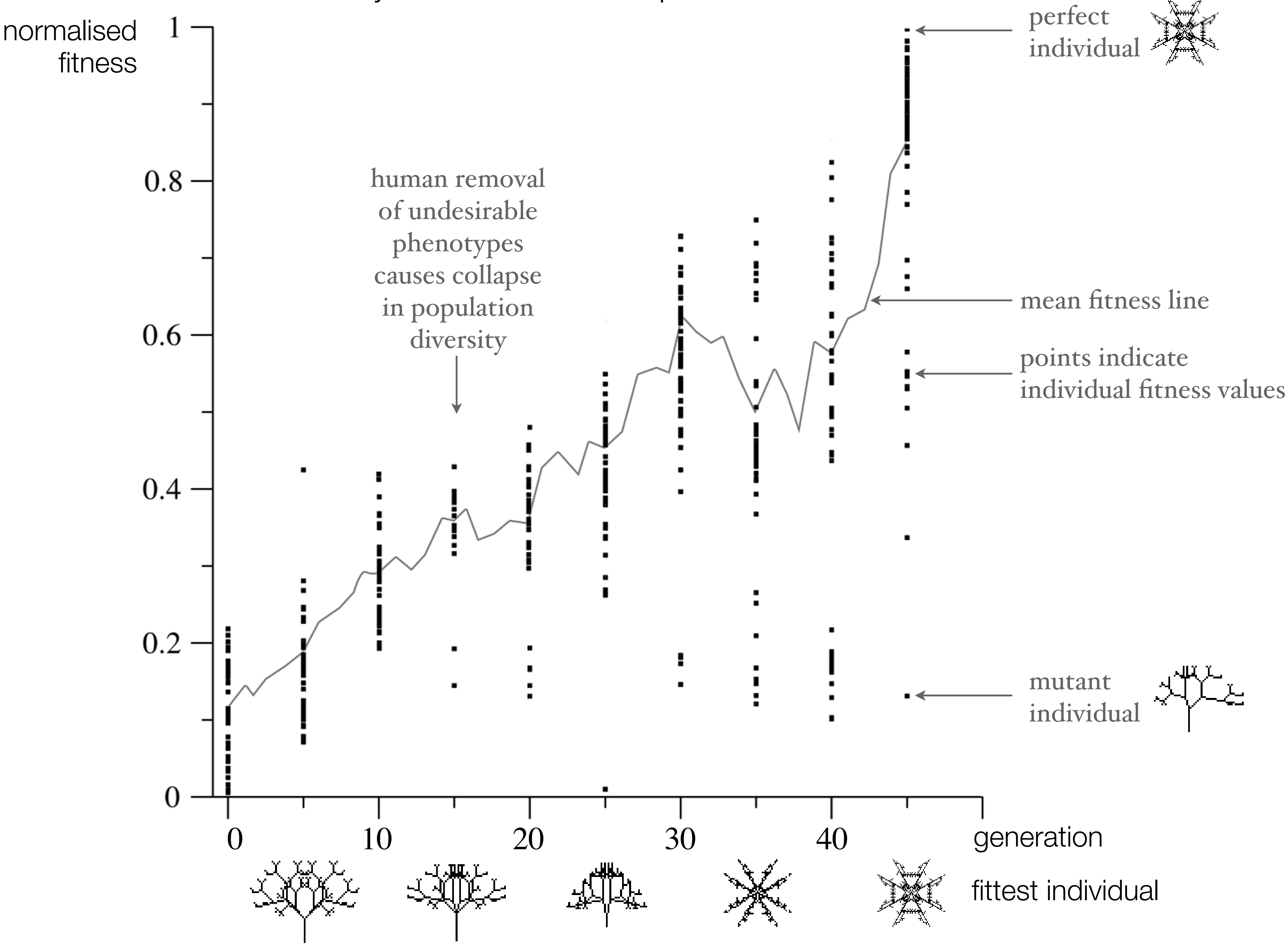
Fitness versus time

The arrow could be labelled on the diagram (presumably its meaning is explained in the text)



This graph is a little coarse — fine lines are clearer indicators and would show that the diagram has been prepared with care and accuracy. Otherwise this graph is not bad

Partially Automated Biomorph Evolution*



* a fictitious graph prepared for demonstration purposes only

before we move on...

Are there any questions or comments?

On to fitness landscapes...

An aside, the fitness landscape

An uninformative fitness landscape with an equally uninformative caption designed for "illustrative purposes" on the Wikipedia

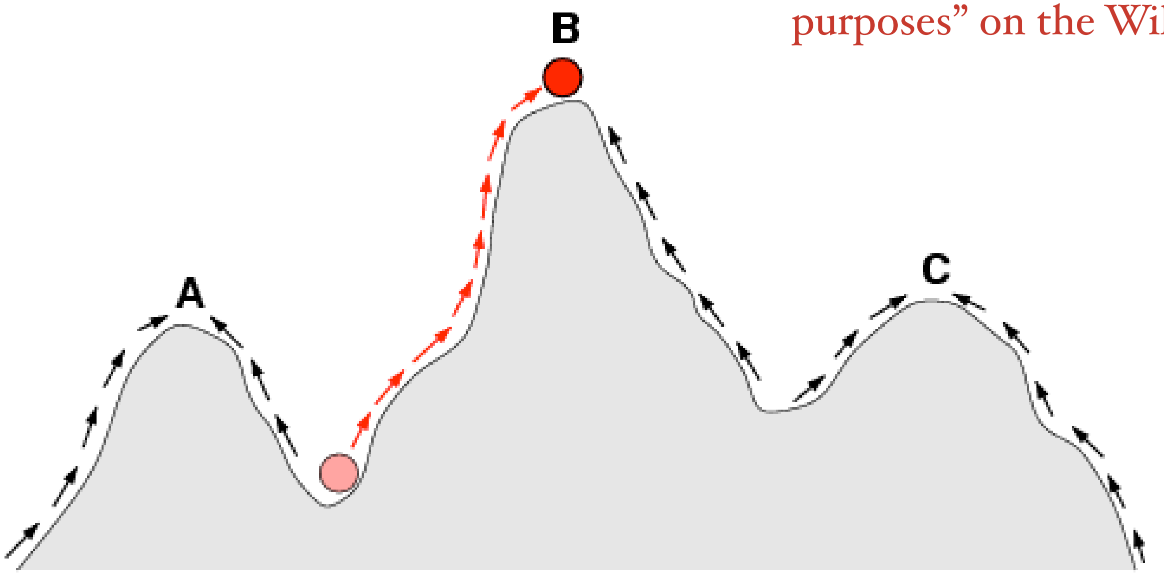


Figure 1: Sketch of a fitness landscape. The arrows indicate the preferred flow of a population on the landscape, and the points A, B, and C are local optima. The red ball indicates a population that moves from a very low fitness value to the top of a peak. Illustration by C.O. Wilke, 2001.

A re-design of the previous fitness landscape

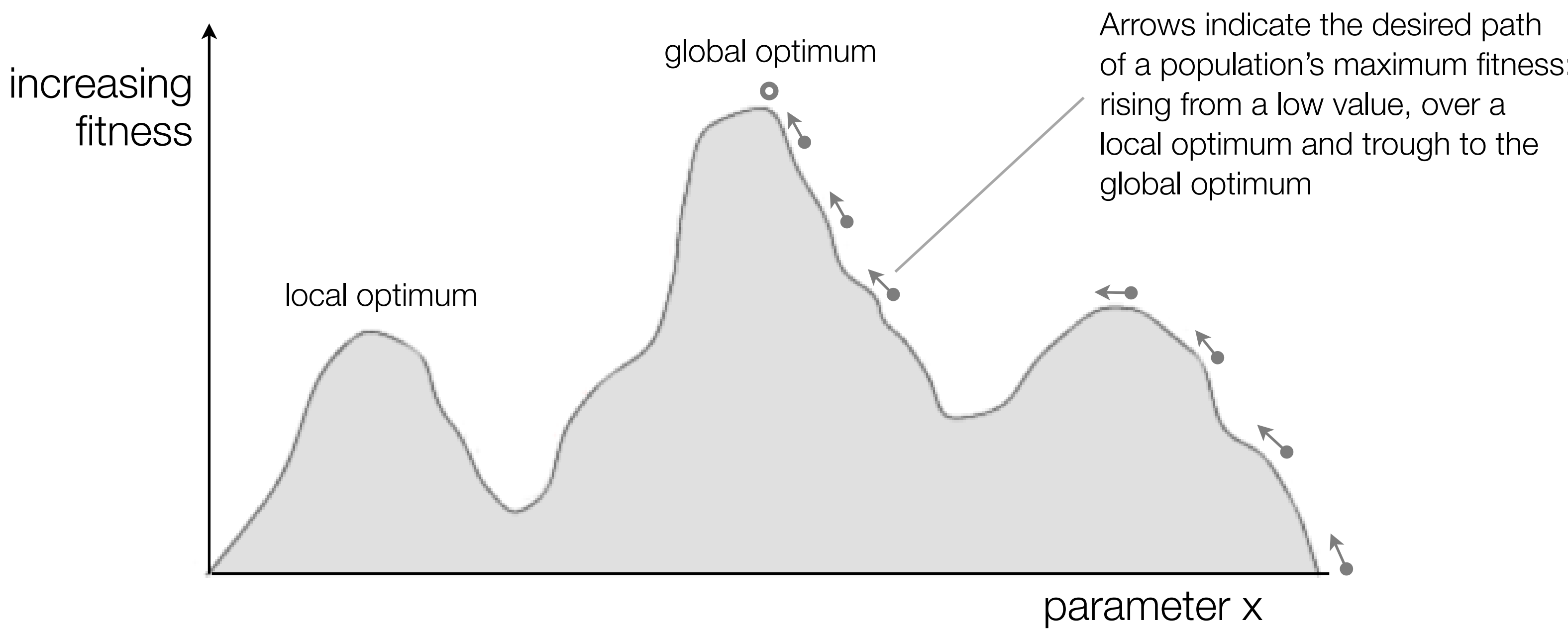
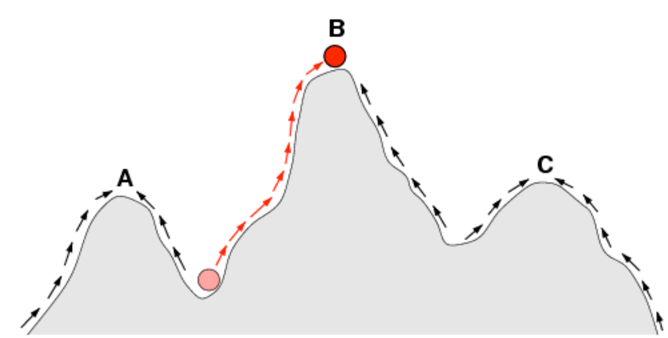
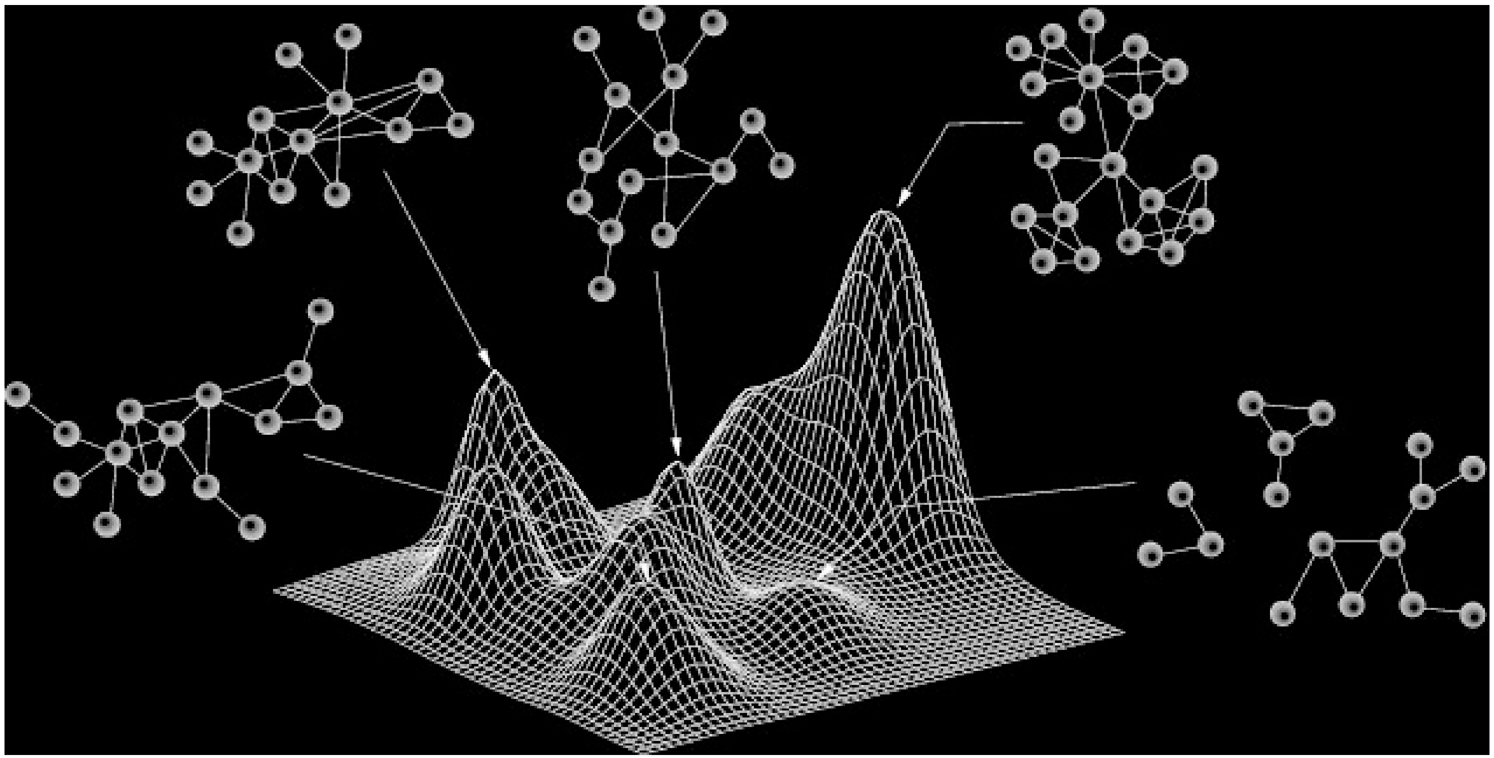


Figure 1: Sketch of a fitness landscape. The values of parameter x as tested by the genetic algorithm give rise to troughs and peaks of fitness giving the appearance of a landscape



A fitness landscape with small multiples



conveniently leads us to discuss small multiples...

Small multiples displaying the results of a method for locating hand positions on a series of fitness test cases.

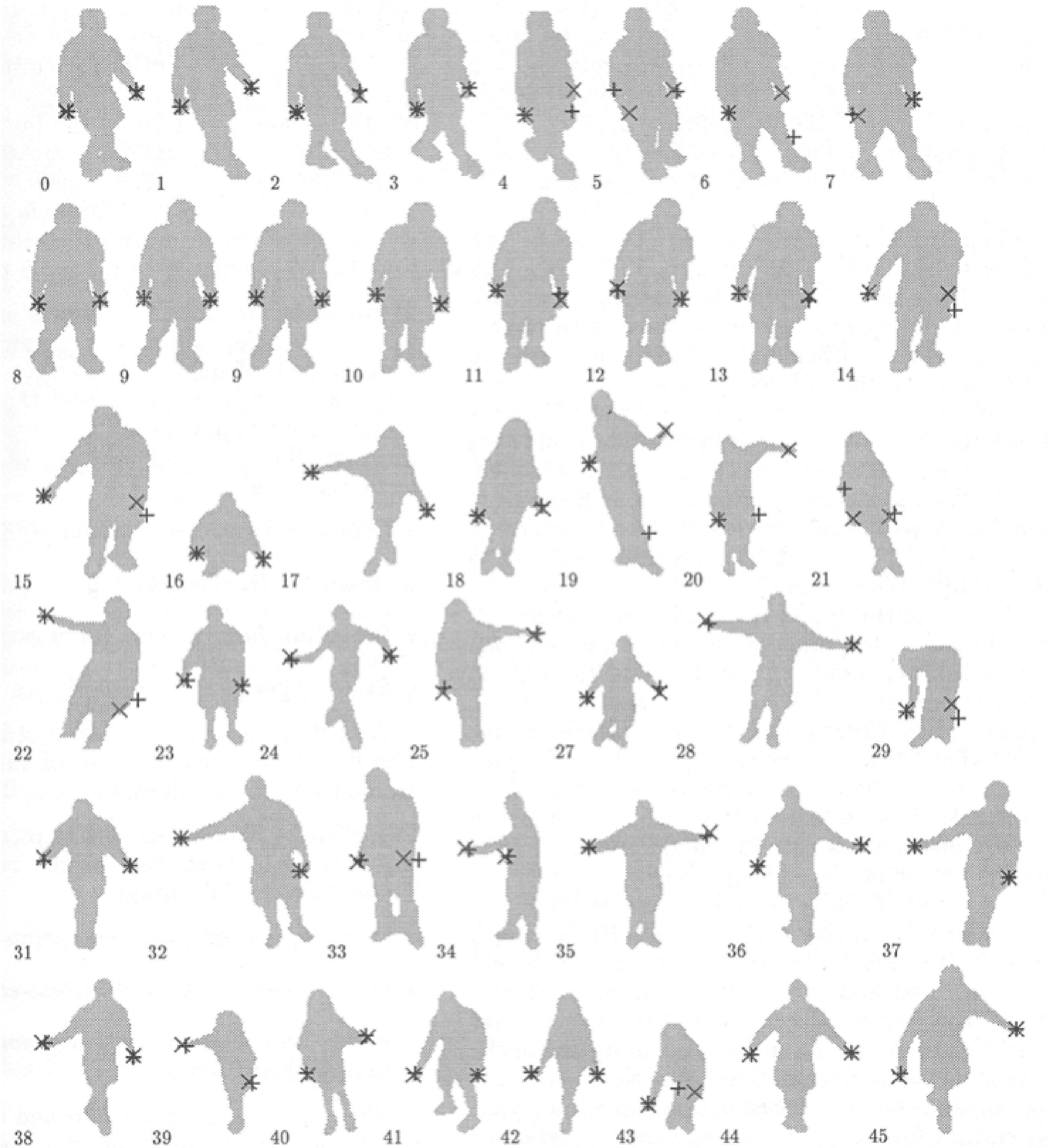


Figure 1: Fitness Cases. X shows the desired location. + shows the best program's result.

Johnsson et al, Proceedings of Artificial Life IV, p201

Small multiples laid out for comparison of distance travelled in an animated display

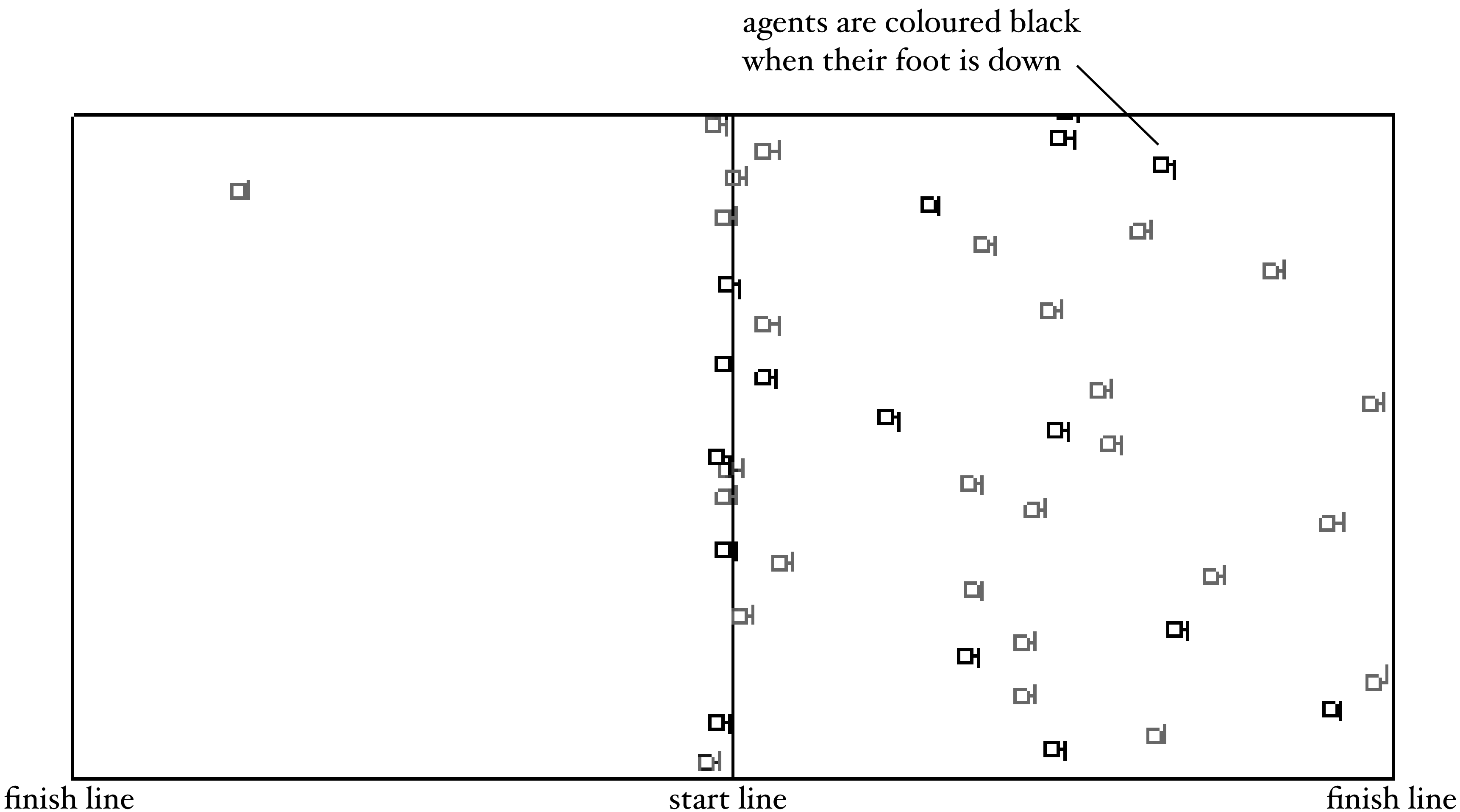
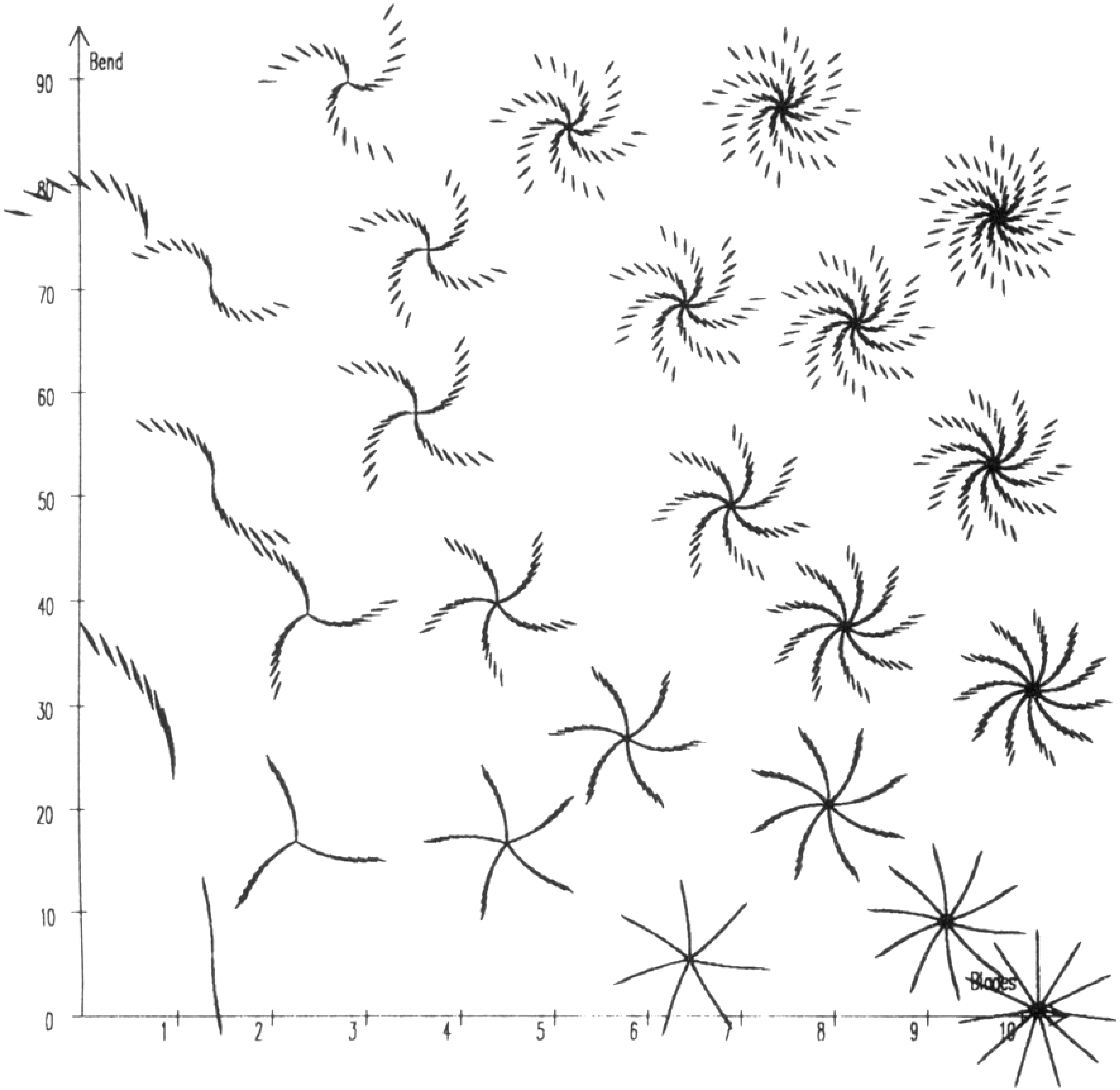


Fig. 1. A snapshot of an animated display showing a number of simple agents that push or pull themselves right or left from a start line to a finish line

Small multiples laid out in a hierarchy to show genealogical relationships

William Latham 1992

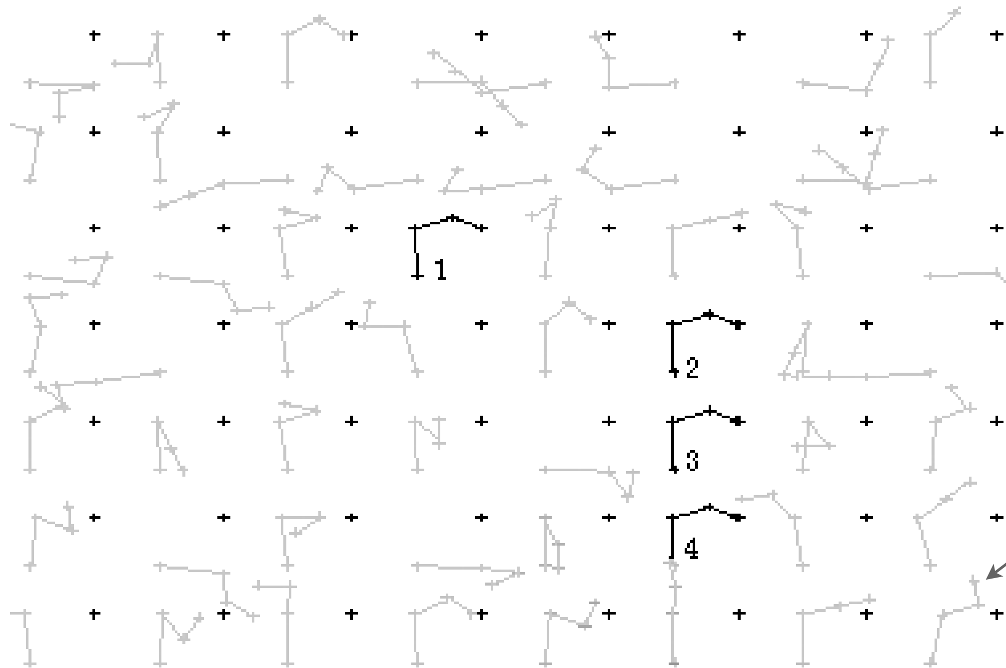


Small multiples laid out along axes to show variation of a parametised form

William Latham 1992

Small multiples laid out in grid

Robot-arm bases are not *visually* distinguished from end-effectors



robot-arm end-effector

robot-arm target

robot-arm base (anchored)

Figure 1. A snapshot of an animated population of articulated robot-arms undergoing automatic evolution to touch a target with their end-effectors

This grid of small multiples is too tightly packed to clearly associate a robot-arm with a target

Robot-arms that have touched the target are highlighted and numbered for reference in the text

Small multiples overlaid

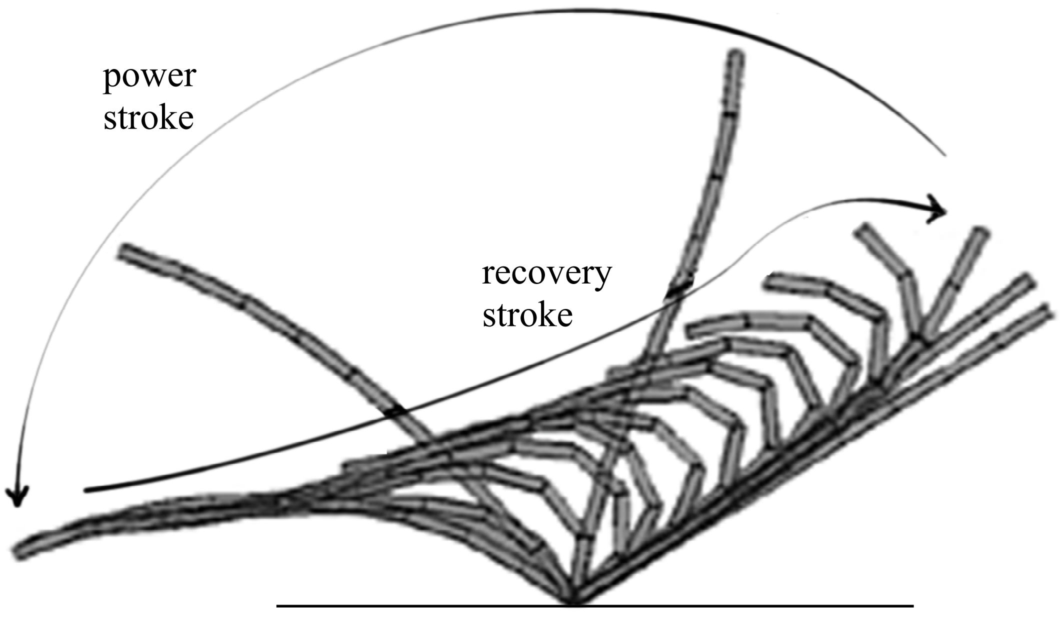
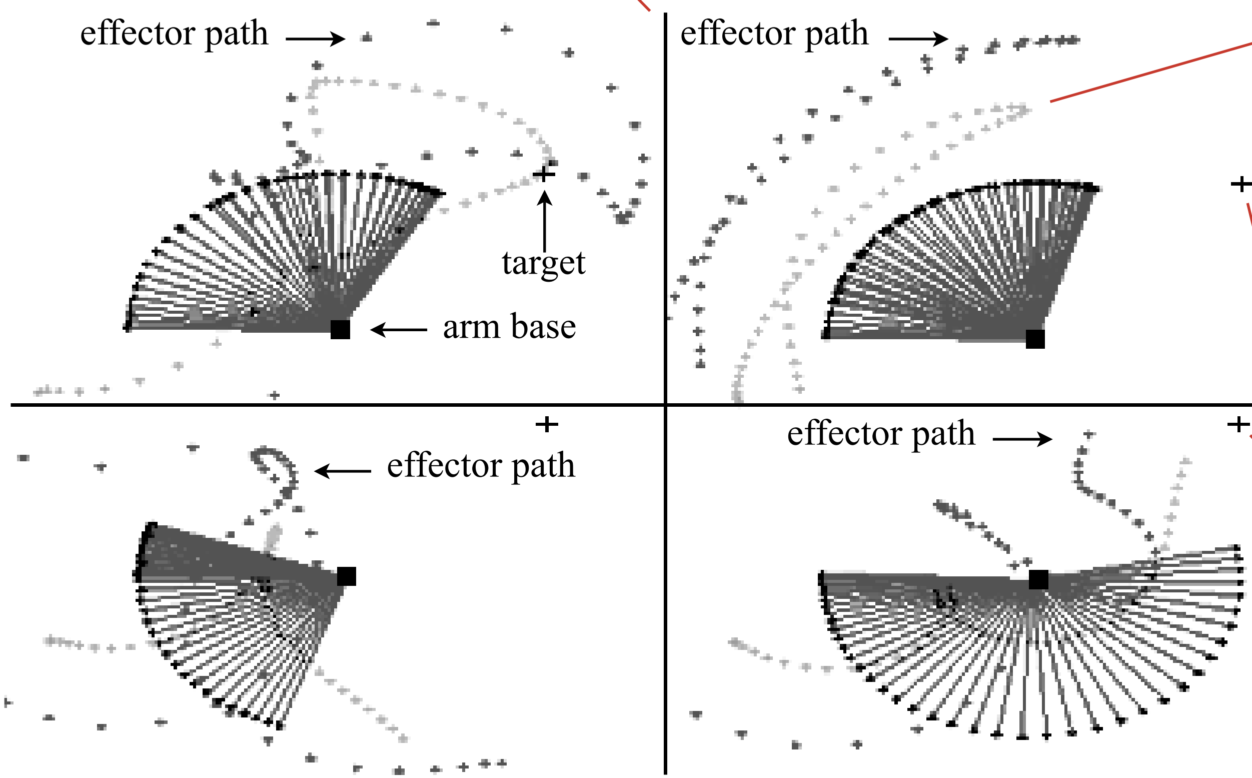


Figure 1. The movement of a simulated cilium

Strokes are clearly labelled. Arrows show direction, stroke width shows speed

Small multiples of overlaid small multiples

Prefer blank space instead of lines to separate small multiples



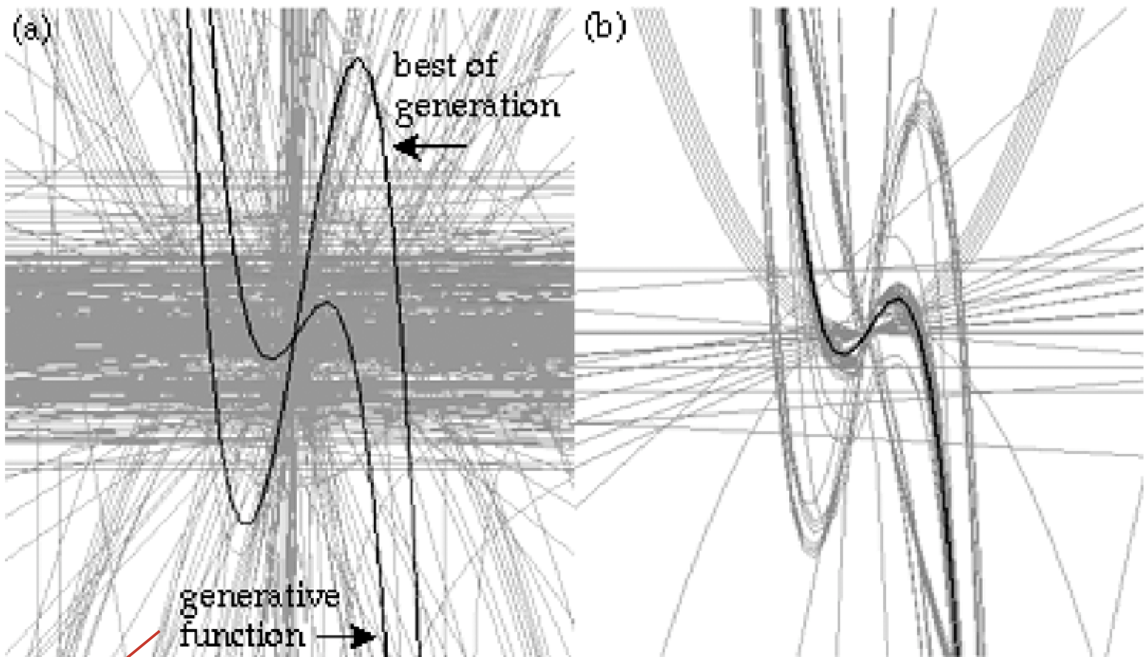
Joint paths of effectors are clear only when they don't cross

The paths may have been clarified using finer lines

Shifting the frame between multiples is confusing (Compare target positions in these two frames)

Two small multiples of countless overlaid small multiples

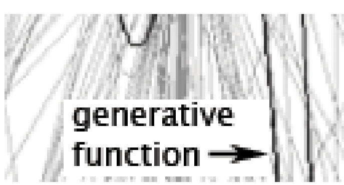
best of generation overlays generative function



(a) population at generation 20

(b) population at generation 150

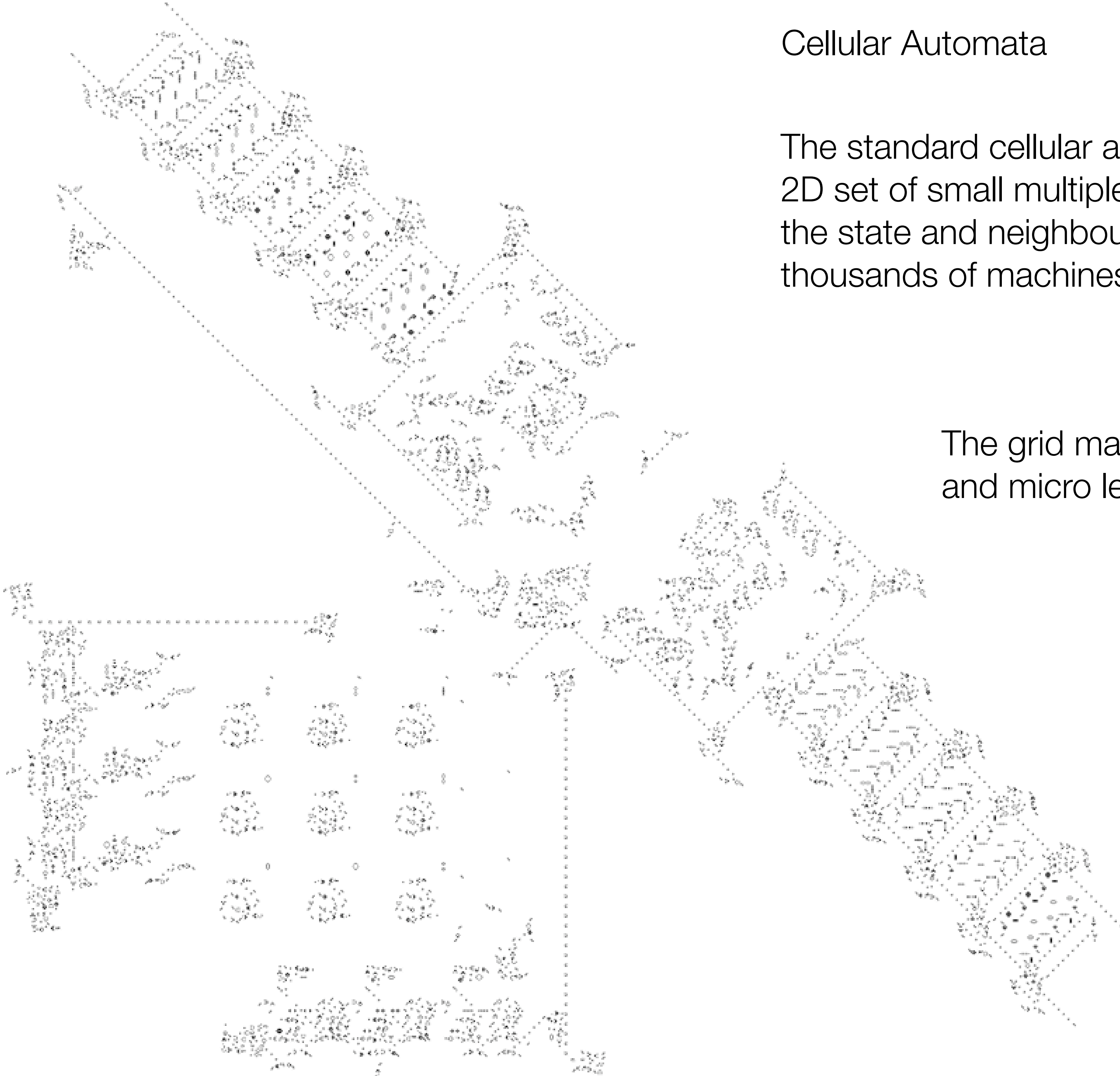
Text can be made legible by placing it in white space where critical data is not obscured



Despite its problems, this is an effective presentation using overlaid small multiples to allow *comparison* of the population's diversity at two different times before we leave genetic algorithms...

Are there any questions?

On to cellular automata...



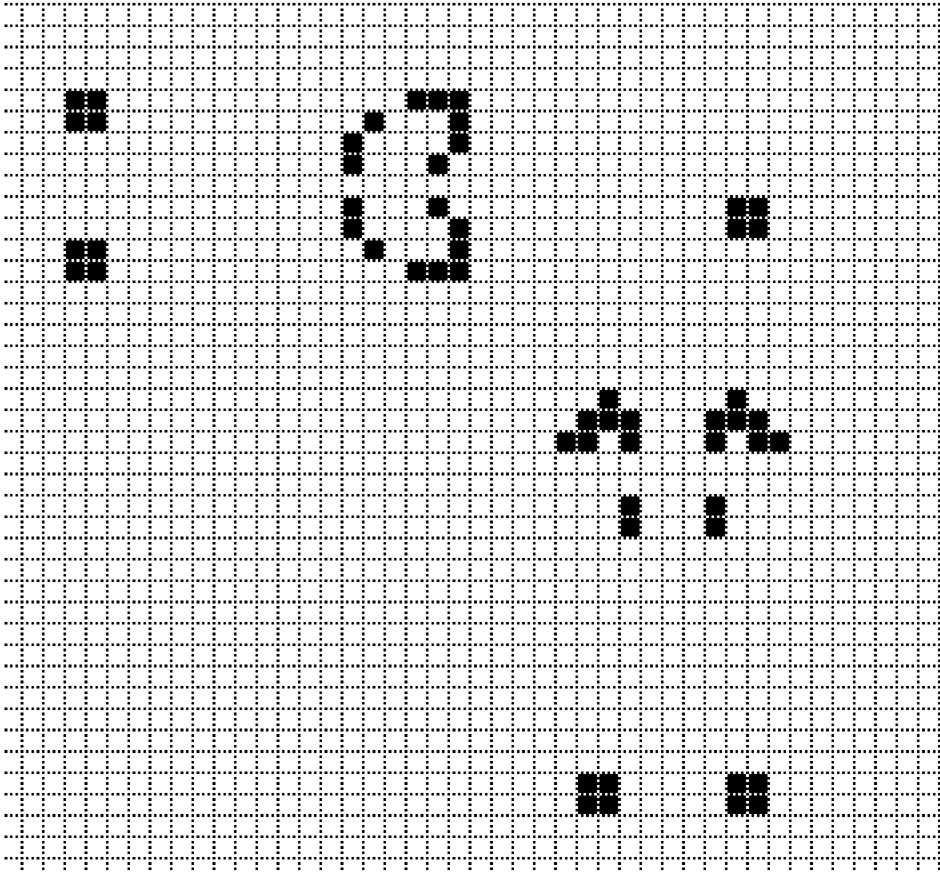
Cellular Automata

The standard cellular automata grid is an ordered 2D set of small multiples. It simultaneously shows the state and neighbourhood relationships of thousands of machines

The grid may be read at both macro and micro levels

Paul Rendell http://rendell.server.org.uk/gol/turing_js_r.gif

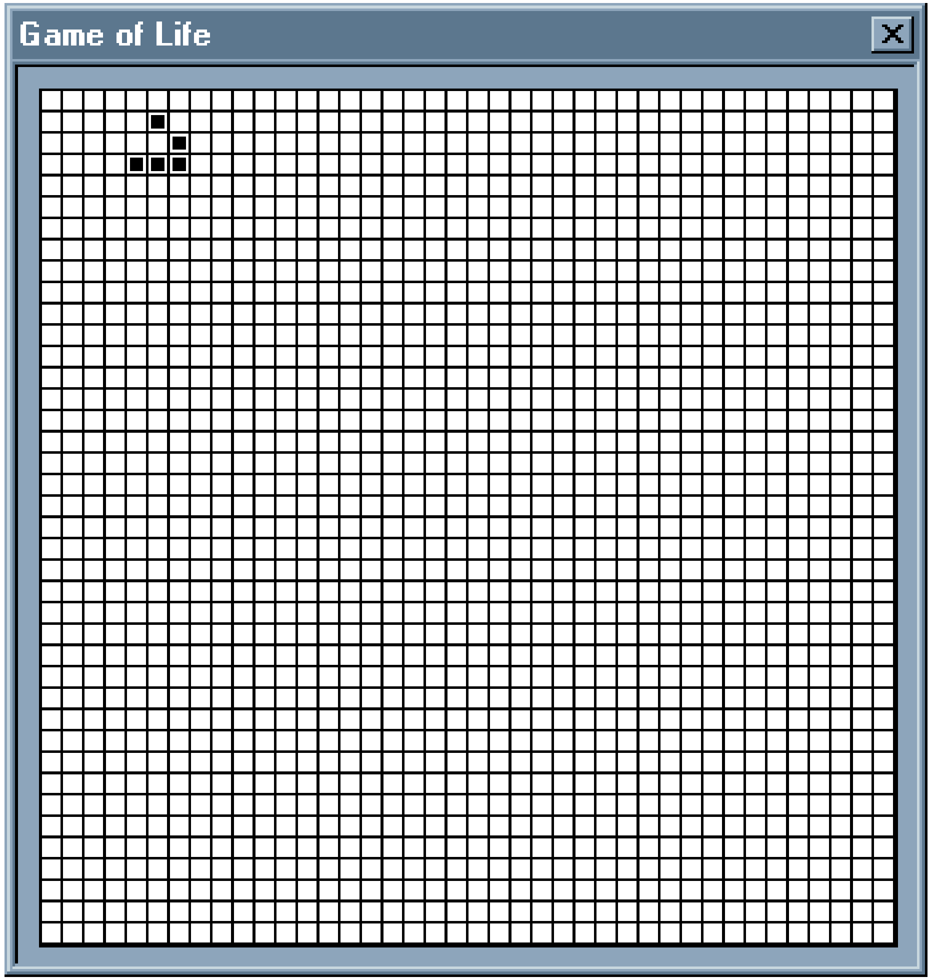
Cellular Automata



Steffen Christensen www.scs.carleton.ca/~schriste/life/

A subtle visual grid is often necessary to allow the viewer or interacting user to determine the exact number of cells in a formation

However, the grid must not dominate the visualisation

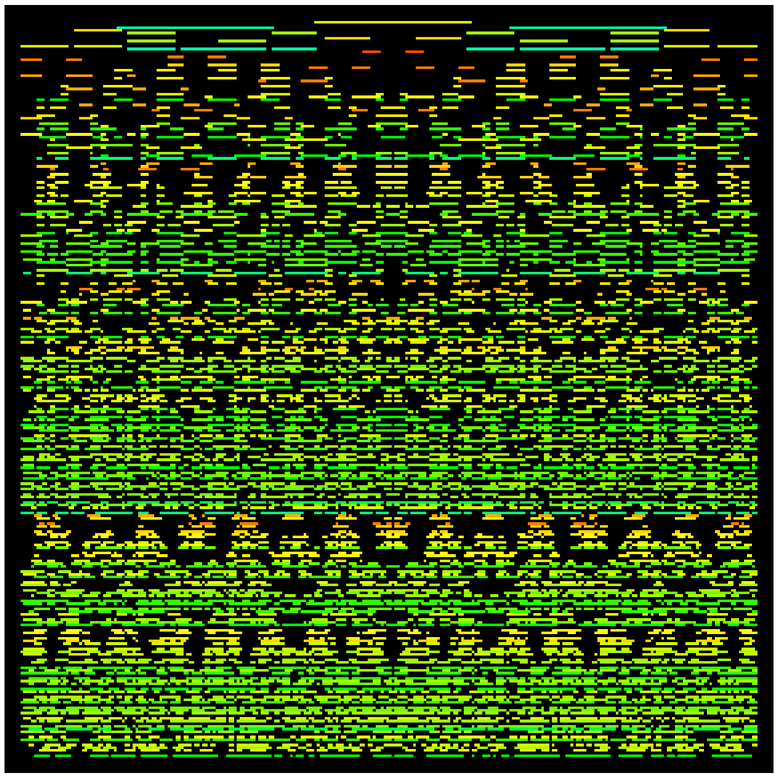


Eduardo Reck Miranda website.lineone.net/~edandalex/camus.htm

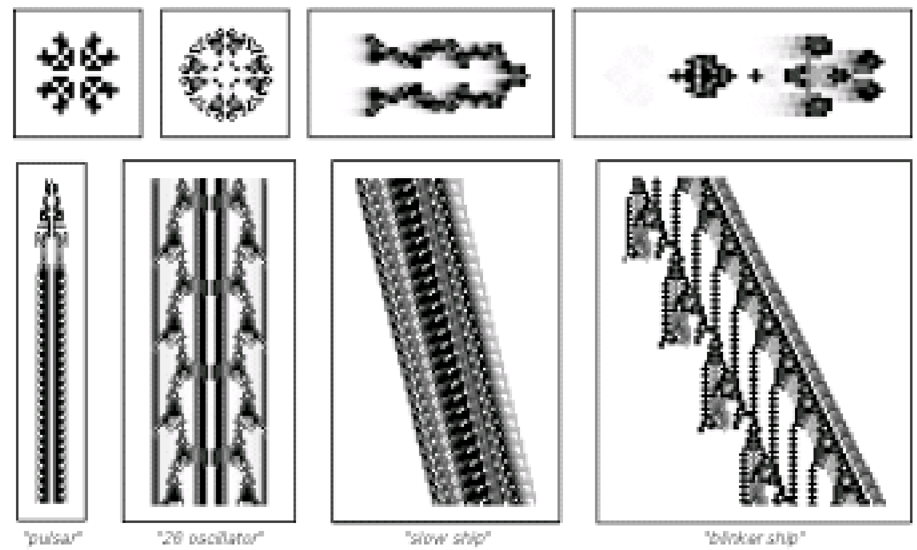
Cellular Automata

The addition of colour can increase the amount of data displayed on the cellular automata grid by an order of magnitude or more, and the degree of visual confusion.

Be subtle with your contrasts



Grey-scale can be just as effective



Oliver Knill abel.math.harvard.edu/~knill/oldinterests/cell/node3.html

Stephen Wolfram www.wolframscience.com/nksonline/bookimages/page0964g.gif

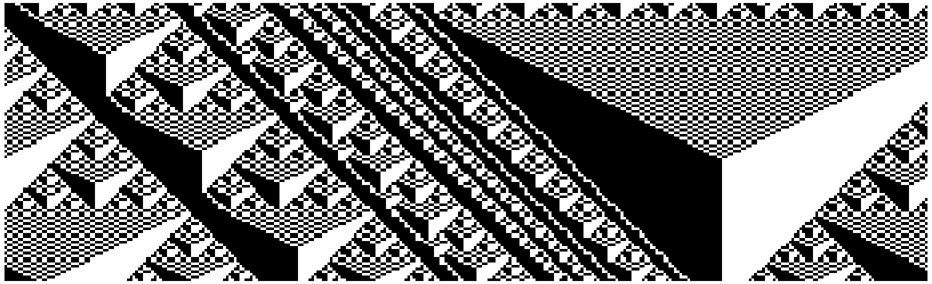
Cellular Automata

Small multiples stacked horizontally make up a strip cellular automata

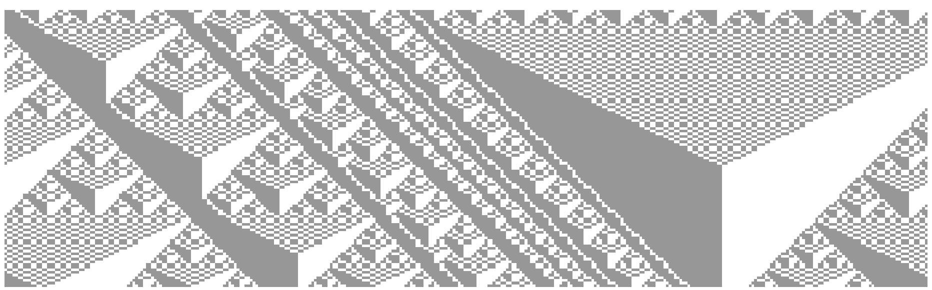
Strips multiplied vertically merge into a pattern with characteristics of its own

Individual lines of this pattern shown sequentially will not reveal (for example) that triangles emerge from the system over time because the triangles only exist in time

However, superimposing the strips in an animated display will reveal other characteristics such as the transmission of a pulse left or right across the strip



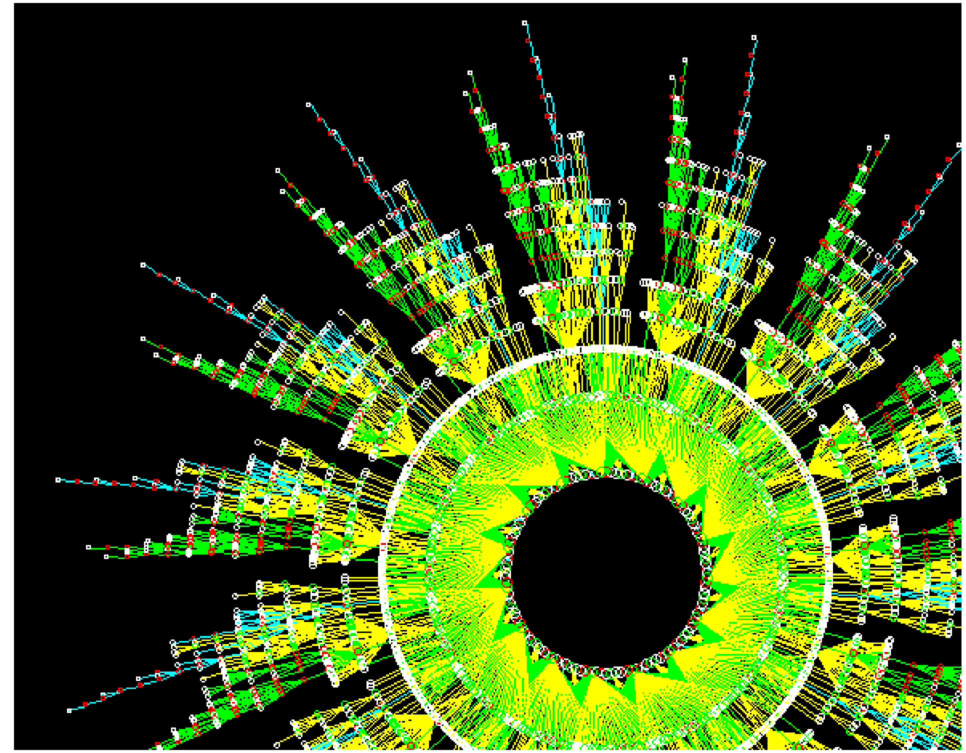
Strong black and white contrast in this image generates unwanted visual noise in the form of Moiré patterns



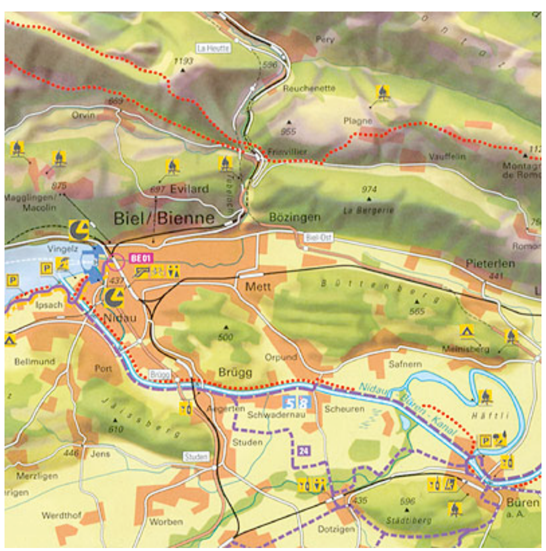
Lowering image contrast can help quieten these unwanted effects. Sometimes it may be impossible to eliminate them altogether

The Global Dynamics of Cellular Automata
Andrew Wuensche & Mike Lesser

original
colours

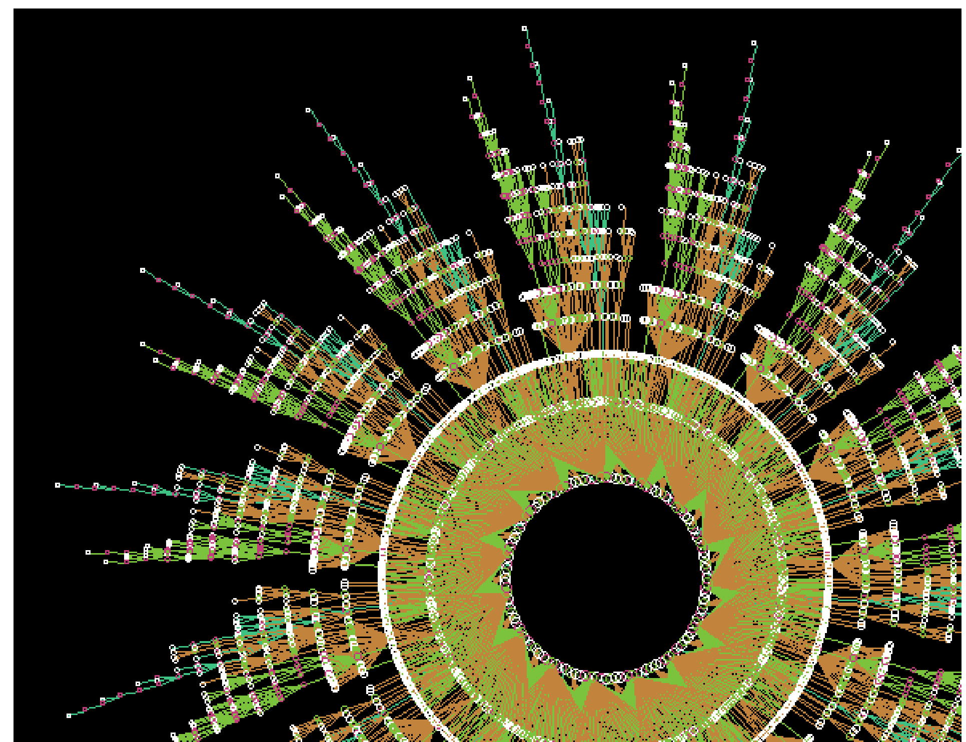


For colour examples look, as before, to cartography

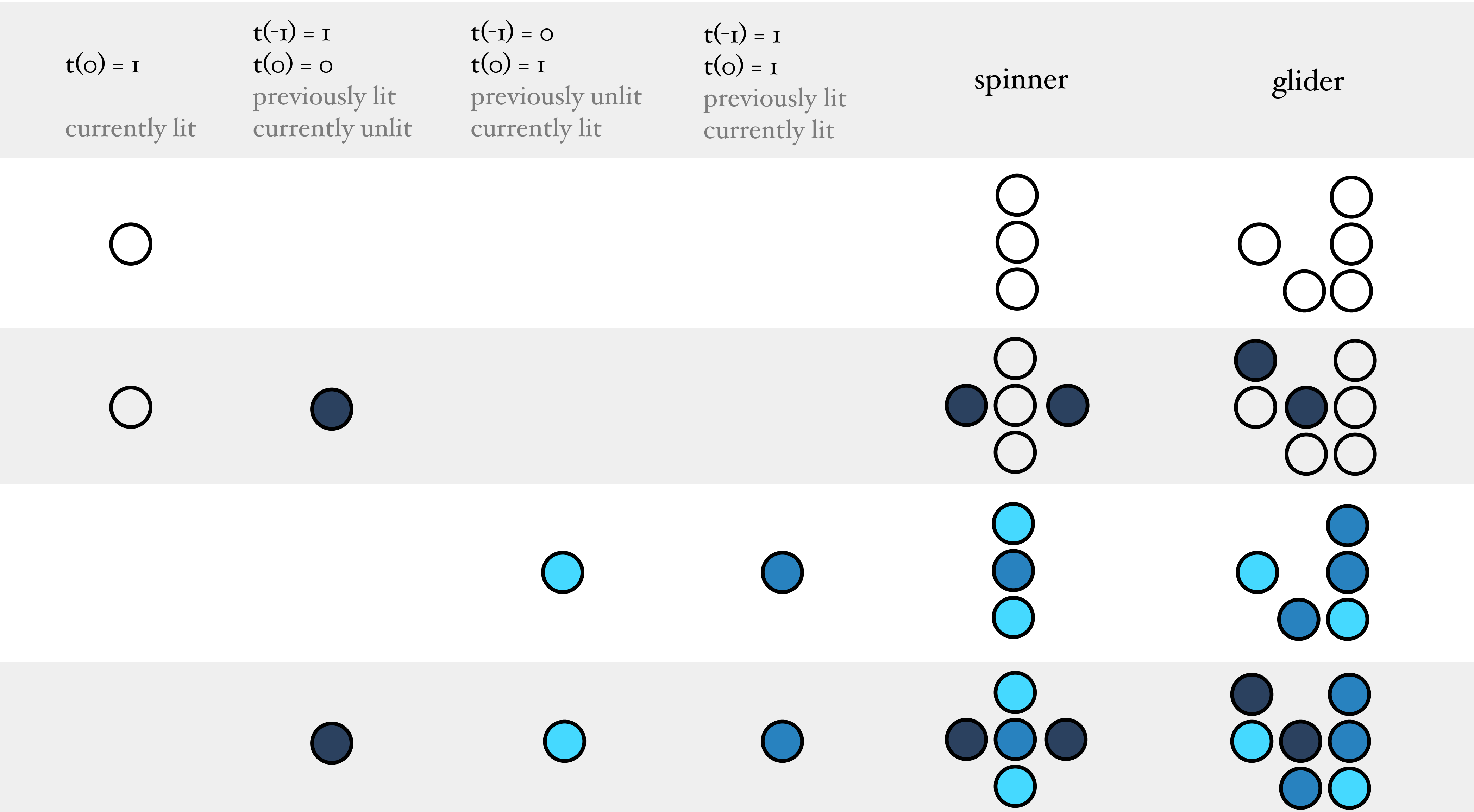


Wäger & Partner GmbH Institute of Cartography, ETH Zürich

de-saturated
colours



Cellular Automata : Conway's *Game of Life*



Possible methods of representing two common structures statically

...and unsatisfactorily. Sometimes, temporal media are far superior...

before we leave static media...

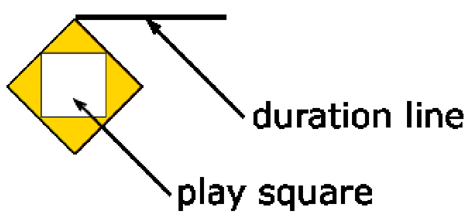
Are there any questions?

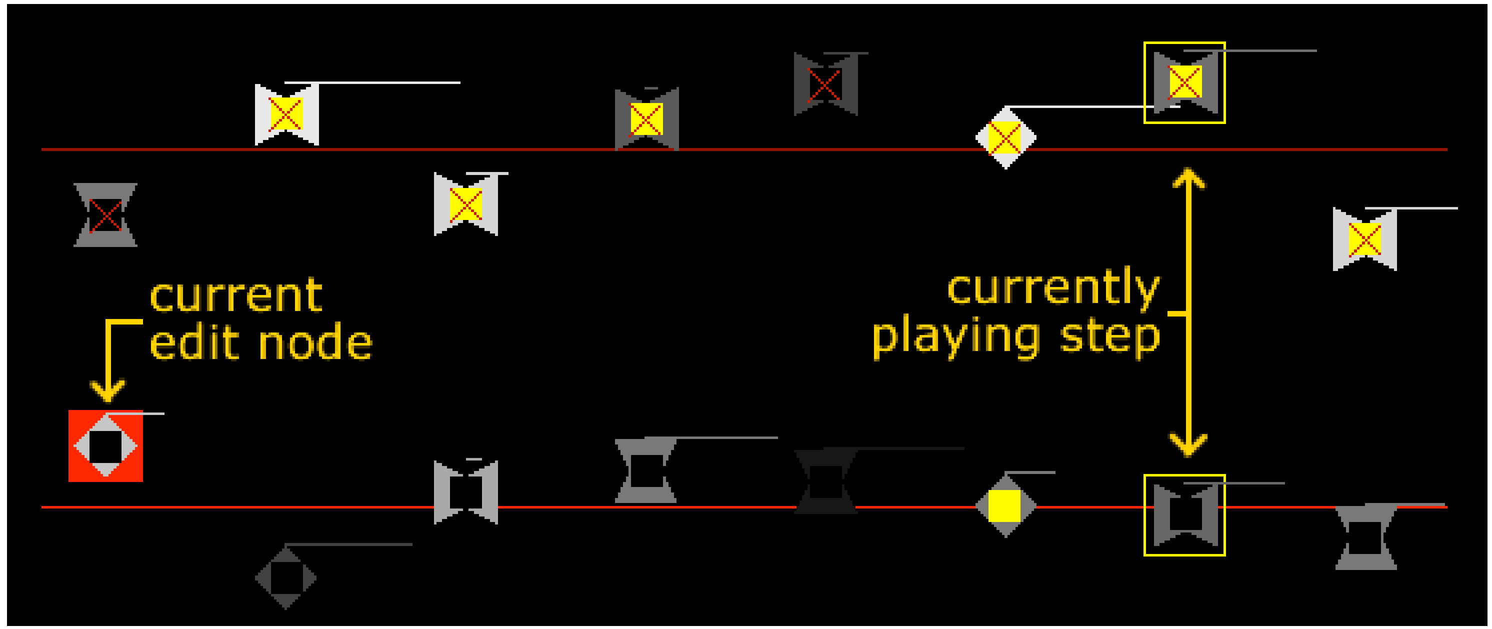
On to dynamic media...

Even your 21” flat-screen display is a low-resolution device...

Rule 1	for screen-based displays, fill the screen with *useful* information, not boxes, decorations, shading, outlines — make every mark on the screen count, at *least* once
Rule 2	everything just discussed for designing static displays is relevant to designing mobile, screen-based displays
Rule 3	...and more

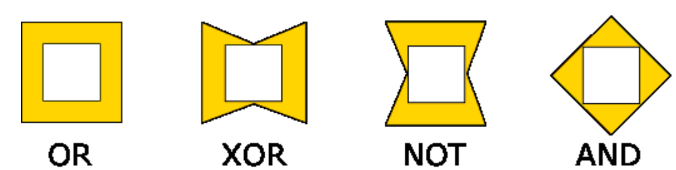
An unusual music sequencer

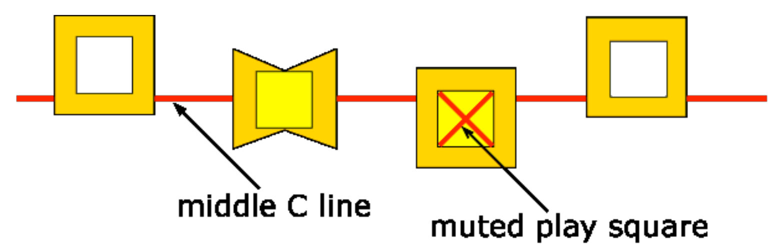




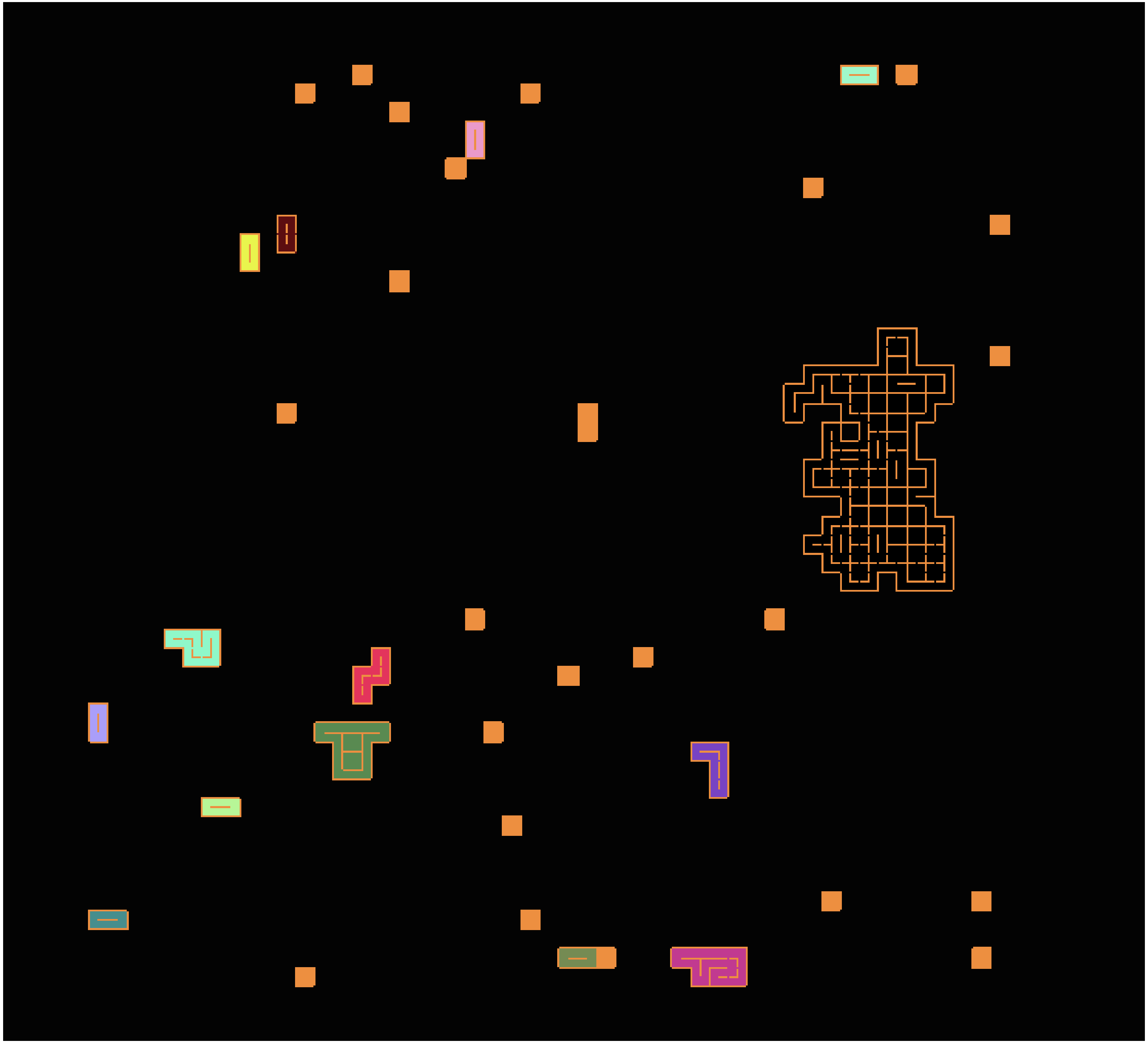
Each icon visualises

volume	grey level
pitch	vertical position
sequence	horizontal position
play-silence-mute	yellow, white, X centre
behaviour	shape

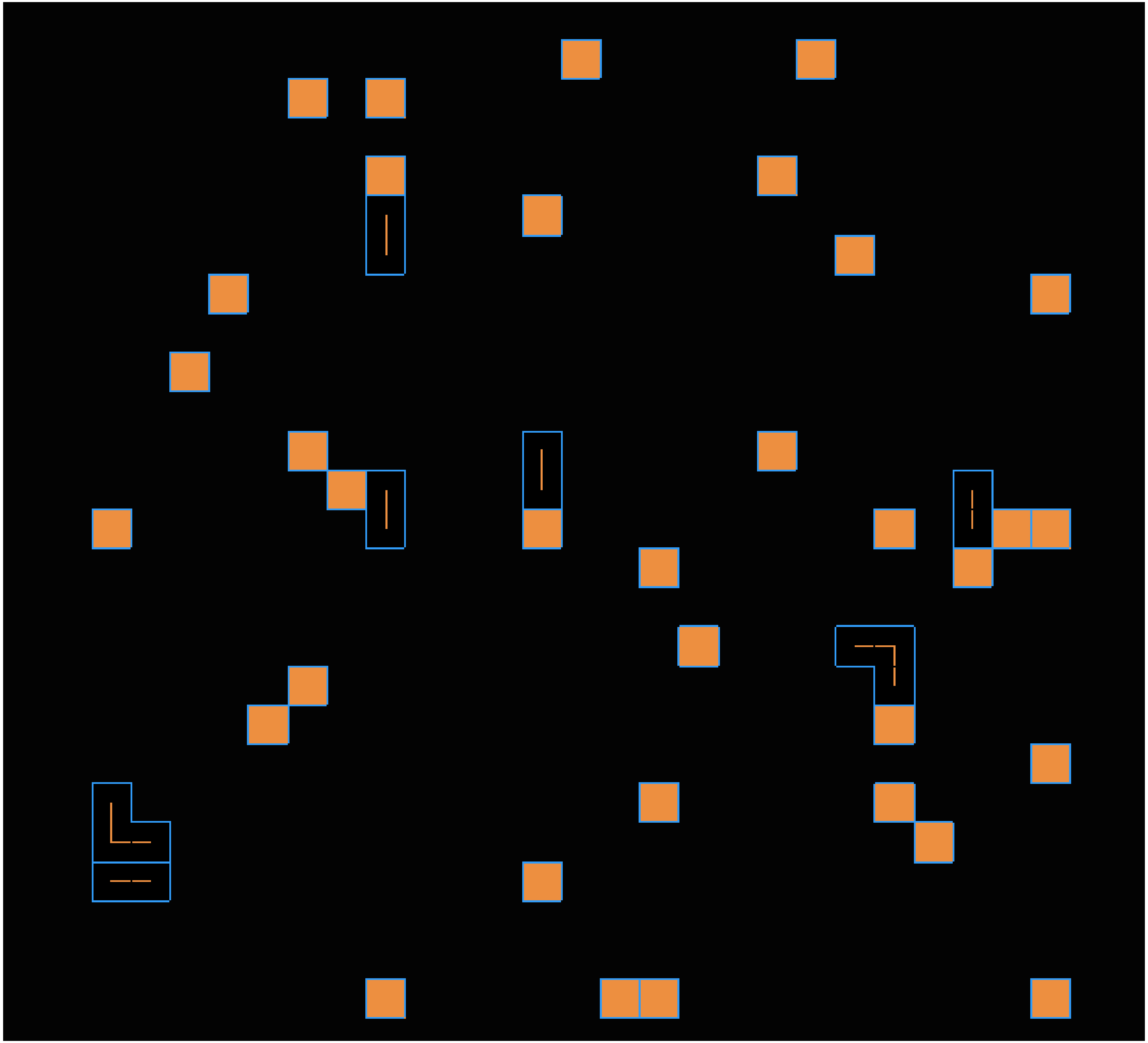




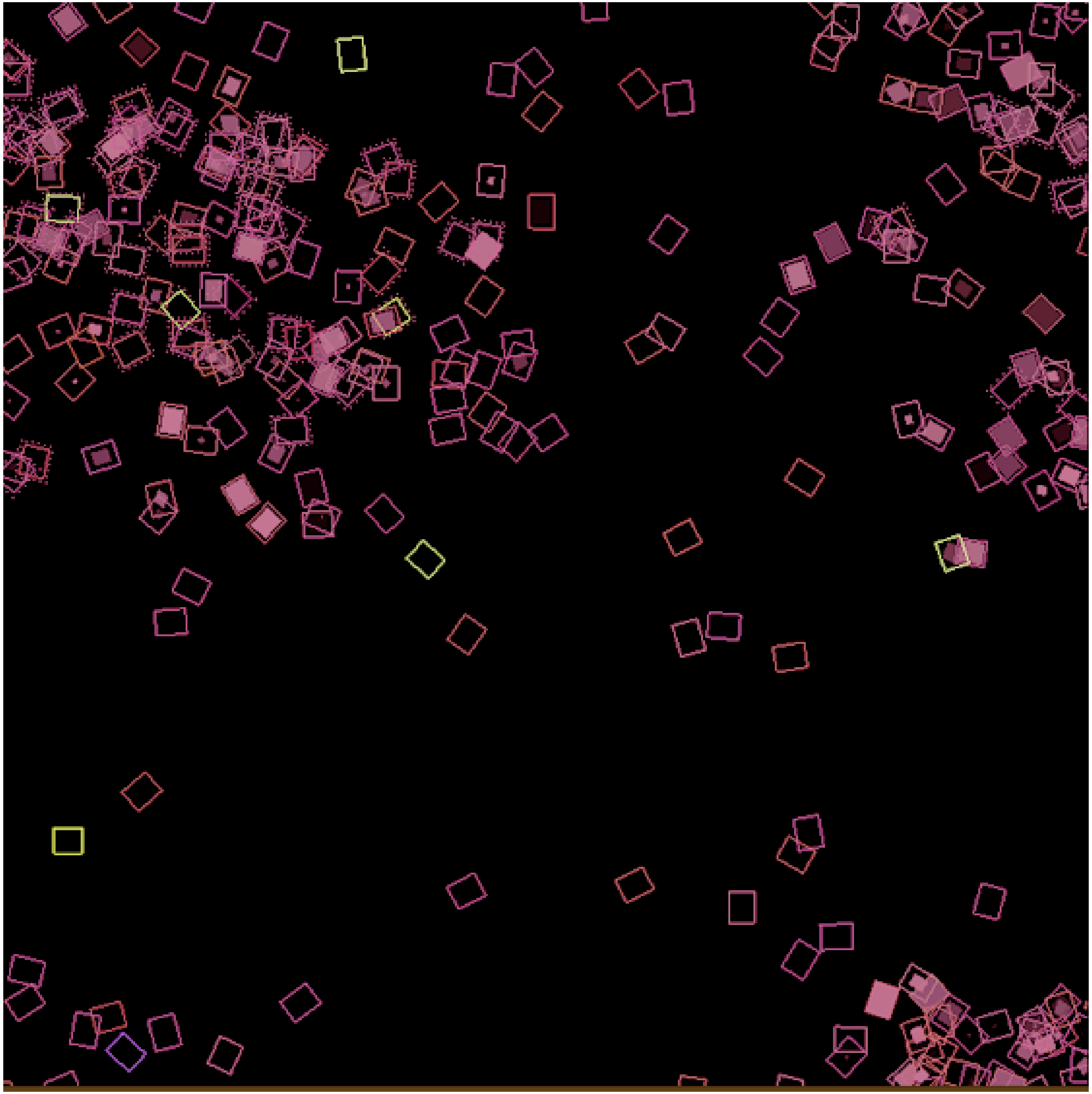
Dynamical hierarchies



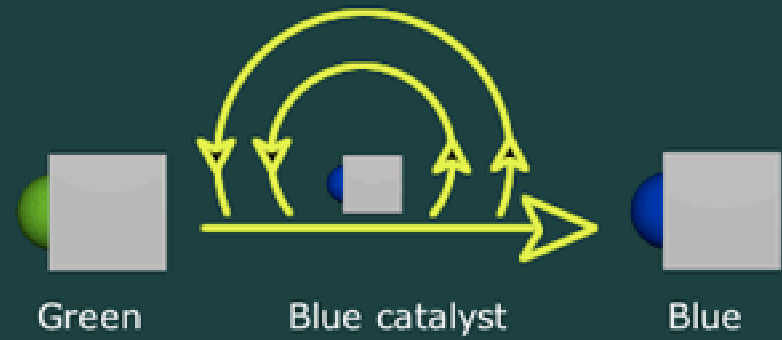
Dynamical hierarchies 2



Agent simulation



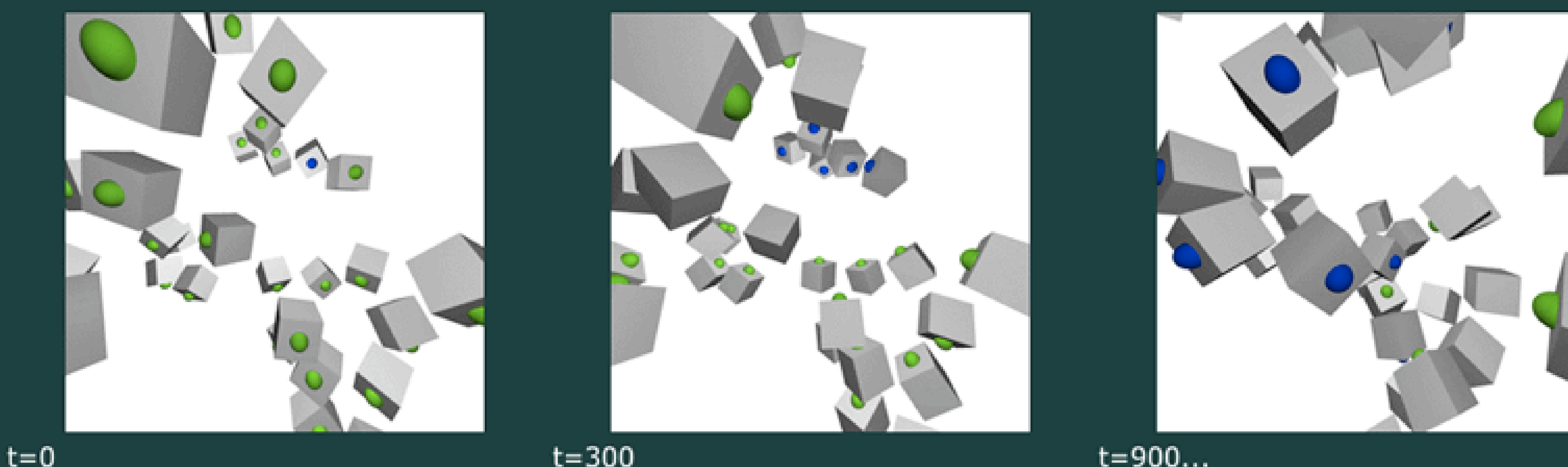
Artificial Chemistry (auto-catalysis)



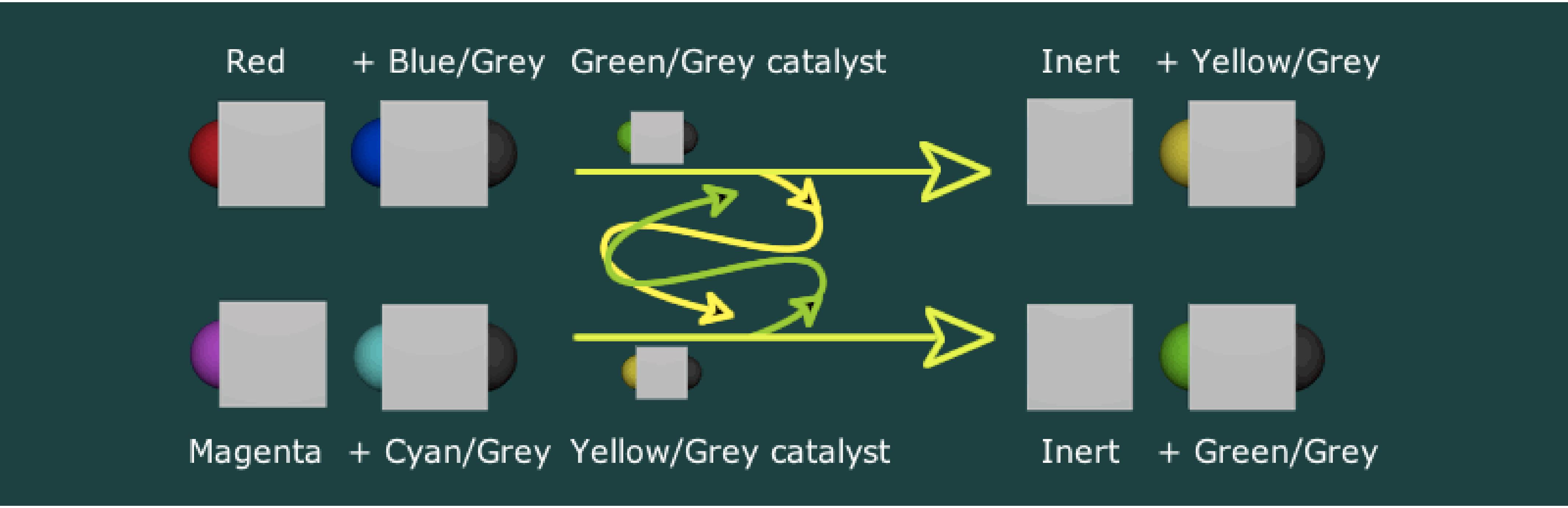
Forces: Green >attract< Blue

Blue <repel> Blue

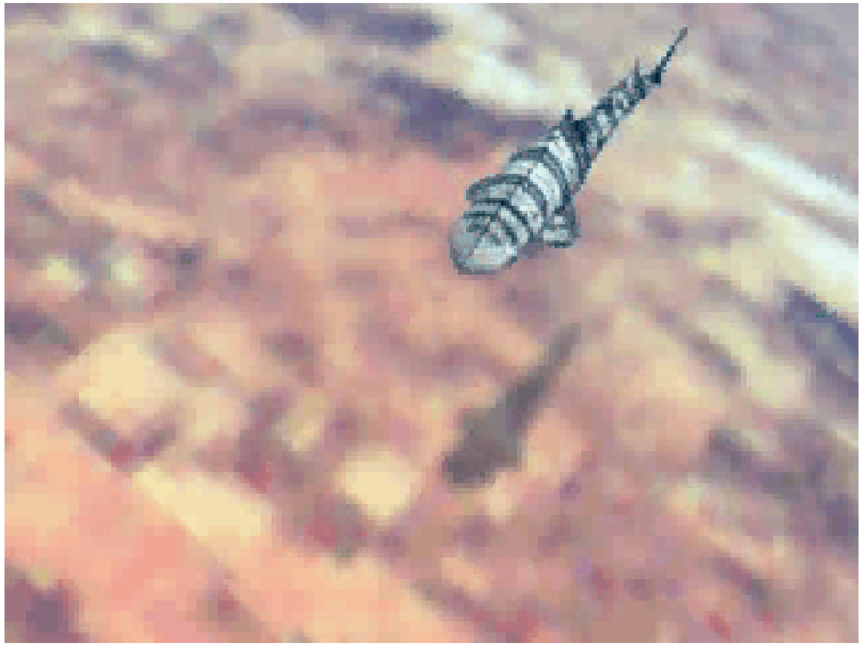
Transitions: Green -> Blue (in the presence of Blue)



Artificial Chemistry (cross-catalysis)



Visualising the evolution of motor controllers



Grzeszck, SIGGRAPH 95

Would we have ever discussed the idea of *emergence* in artificial life if mobile displays had not been available?

Would we have ever debated the *life* of our constructions if mobile displays of our data had not been available?

Stop clicking slides Alan
you've babbled enough