# Selfish Memes & Selfless Agents - Altruism in the Swap Shop

David Hales
(e-mail: daphal@essex.ac.uk)

Department Of Computer Science
The University of Essex,
Colchester, Essex, UK

## Abastract

A "memetic" (Bura 1994, Dennett 1995, Hales 1997) approach is applied to a resource sharing scenario. “Agents" are represented as cells on a grid applying simple cultural learning rules which selectively replicate and repel memes from neighbours. The memes represent culturally learned traits (Axelrod’s 1995) but also influence resource sharing behaviours.

In the experiments presented, multiple cultural groupings which become altruistic towards "in-group" members via a form of group selection (Pedone & Parisi 1997) emerge.

This form of cultural evolution is offered as a unified approach to the study of group formation, cultural evolution, cooperation and altruism. Memes are viewed as the basic replicators upon which societies are constructed.

It is demonstrated that such methods can produce more optimal societies than conventional evolutionary methods in given situations. The memetic approach is inherently distributed and dynamic, offering the possibility of application to areas such as collective robotics and software agent co-ordination.

**Topic Areas:** Cooperative problem solving, Coalition formation & organisation self-design

## 1 Introduction

Within DAI and the game theoretical literature a fundamental question is often posed: Given bounded rationality and knowledge, what conditions produce cooperative and/or altruistic inter-agent behaviour?

One line of enquiry involves the application of simple learning rules within game theoretic environments (Liebrand & Messick 1996). This approach assumes that agents are individual satisficing learners. Another approach applies selective mimicry from a spatial "neighbourhood" based on maximum payoff (Nowak & May 1992). Although elegant, and able to produce cooperation, neither can produce sustained altruism - where individual needs are driven by the needs of a group to the individuals detriment.

Here, a fresh perspective on cooperation is applied which is a synthesis of these two approaches yet moves beyond them. A “memetic” (Bura 1994, Dennett 1995, Hales 1997) approach is developed which takes it’s inspiration from theories concerning the cultural evolutionary processes in human societies.

It seems that human societies manage to solve many co-ordination and group organisational problems although they appear to become ever more complex, interdependent and expansive. Yet archaeological evidence suggests that the emergence of complex societies is very recent (Mithen 1996). This is too recent for the process to be accounted for as a genetic evolutionary trend. Cultural processes operate at a higher level than genetic processes and are orders of magnitude faster. Is it possible to capture some of the dynamics of such processes? If so, could such processes be applied to MAS’s in order to evolve solutions to co-ordination problems?

I attempt to address these two questions using the “meme” conception (Dawkins 1976). If “cultures” are decomposed into units which can be communicated (replicated) and mutated, this can be a basis for a model of cultural evolution in the abstract. Such units of culture have been termed “memes”. A successful meme is one that gets replicated and becomes numerous in the population, not necessarily one that benefits those who hold it. Previous work (Hales 1997) has examined some of the conditions under which “harmful” memes (from the standpoint of resource use optimality) can become dominant and some of the mechanisms that can breakdown such processes. Here a model is presented that attempts to harness the power of “group selection” based on social influence (Pedone & Parisi 1997) in order to evolve efficient groups of co-ordinated agents where agents have only simple satisficing, learning rules.

In the experiments presented, multiple cultural groupings emerge. The groups become altruistic towards "in-group" members via a form of group selection. This selects for altruistic in-group behaviour, even when this is to the detriment of some individuals within those groups. Eventually the memetic approach produces a homogenous and altruistic culture, this is contrasted with a “genetic” approach which results in less optimal configurations of competing groups.

## 2 The Swap Shop Model

The Swap Shop (SS) is a Cellular Automata "type" model. Strictly, it is not a CA since it does not apply synchronous updating. An asynchronous implementation was chosen to avoid artefacts (see Hagselmann 1996). The framework of the SS is modelled after the Axelrod Cultural Model (Axelrod 1995). In ACM Axelrod investigated the emergence of spatial regions of shared "cultural attributes", from simple individual attribute propagation rules. Of primary importance in AMC is the concept of "cultural distance". Attribute propagation only takes place between cells when they share at least one attribute. In ACM cells are purely collections of attributes, the attributes have no behavioural impact. In SS the attributes are viewed as memes which can influence the behaviour of the cells.

### 2.1 Cells And Memes

The SS comprises a 2 dimensional grid of cells. Each cell represents a stationary agent and has four integer state variables associated with it: An energy level ($0 <= EL <= 9$), a sharing level ($0 <= SL <= 4$), a similarity level ($0 <= SSL <= 4$) and a cultural attribute ($0 <= C <= 4$). SL, SSL and C are treated as memes. Consequently they can be propagated and mutated. The values of the state variables determine the behaviour of a cell. The SSL meme indicates the minimum similarity required before the activation of resource sharing with neighbouring cells. Similarity is defined as the number of memes shared between two cells. The SL meme indicates the amount of resource sharing that occurs. The C meme has no direct behavioural impact.

### 2.2 Events And Behaviours

During execution of the SS one of three events can occur: life tax, resource reward and cultural interaction. A life tax event involves a cell's energy level EL being reduced by one energy point (to a minimum of zero). If a zero level is reached then memes may be mutated. A resource reward event involves a cell being awarded four energy points. These are divided between neighbours and the awarded cell in proportions dictated by the SL and SSL values. This is achieved by selecting random neighbour cells (from the Moore neighbourhood) which satisfy the SSL value of the sharing cell and awarding a single energy point if required (i.e. EL of the neighbour is less than maximum). This process is continued until SL points have been shared or some maximum number of neighbours has been selected[1]. A cultural interaction event involves a cell and a neighbour harmonising a single meme given that they have at least one other meme in common. When both cells are culturally identical (i.e. have a similarity of three) cultural interaction will have no effect. Additionally a cell with EL = 0, can never propagate a meme, and a cell with EL = 9, can never receive a new meme. This captures the notion that a “satisfied” cell does not change it’s memes whereas an unsatisfied or “dead” cell can not propagate memes.

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[1] Neighbours are selected at random (with replacement) until all resource rewards have been made or a total of 16 neighbours have been selected. This models a form of "noisy" sharing, where some needy cells may get more than others or nothing at all, but that each has an equal chance of receiving resource rewards.

Note “neighbours” are defined as the eight cells surrounding a cell (the so called Moore neighbourhood). The edges of the SS are not wrapped into a torus, cells at edges therefor, do not have a full complement of neighbours.

### 2.3 The System Cycle

A single "cycle" of the system is implemented as:

```
LOOP for the total number of cells in the grid
  with probability PT (life tax event):
    select a cell (z) at random
    IF EL of z>0 THEN deduct one from EL value of z
    IF EL of z=0 THEN mutate each of SL,C,SSL with probability PM
  with probability PR (resource award event):
    select a cell at random
    award energy points to the selected cell (increase EL by 4)
    based on cell SL,SSL values, distributed points to neighbours
  with probability PC (cultural interaction event):
   select a cell (z) at random
   select a neighbour (n) at random
   calculate the similarity (s) between z and n
   IF s>=1 AND EL of n>0 AND EL of z<9 THEN
     propagate a randomly chosen (differing) meme from n to z
END LOOP
```

For all the experiments presented here, the system cycle was iterated 2000 times. Experiments indicated that beyond this, no significant changes occurred. Mutation involves increasing or decreasing a meme value by one (values out of range are rest to the nearest value in range).

## 3 Four Experimental Scenarios

Four experimental scenarios were designed (A to D). These compare “cultural” with “genetic style” evolution in both uniform and “sparse” reward environments. This later environment designates some minority of cells as “productive” and others as “non-productive”. Resource rewards are only made to “productive” cells. Each scenario is described below.

### 3.1 Scenario A - “Cultural” Evolution

The parameters are set to PT = 1, PM = 0.2, PR = 0.25, PC = 1 with a grid size of 20x20 (400 cells). This implements a scenario where stochastically, energy is taken out and put back, in equal proportion. However, the "life tax" is more evenly distributed than the "resource reward" (specifically in the proportion of 4:1). Initially each cell in the grid is initialised with random values for each of the state variables.

### 3.2 Scenario B - “Genetic” Evolution

The same settings as scenario A are used but a “genetic” style of evolution is applied instead of a cultural one. All cultural interaction is turned-off. When a cell's EL equals zero (after a life tax event), all memes from the neighbour with the highest EL level are copied into the "dead" cell with PM mutation on each meme. This implements a form of local asexual evolution where fitness is based on EL. In this scenario the memes can be viewed as "genes".

### 3.3 Scenario C - “Cultural” Evolution With Sparse Rewards

The same settings as scenario A are used but resources are distributed only to designated cells rather than to all cells. Only cells with even row and column numbers are awarded resources. This means that cells receiving resources have no neighbours who also receive resources and therefor can not benefit from sharing behaviours by others.

### 3.4 Scenario D - “Genetic” Evolution With Sparse Rewards

The same settings as scenario C are used, but the “genetic” style of evolution is used as in scenario B.

## 4. Results

For each scenario 100 individual simulation runs were executed for 2000 system cycles each. Tables 1 and 2 show a synthesis of all the runs for each experiment. These results are discussed below.

Table 1 and Table 2 about here!

### 4.1 Experiment A – Single Region with Total Sharing

Within a few hundred cycles spatial regions of shared meme bundles form. Those regions which satisfy more of their members (i.e. keep them from falling to zero EL) tend to grow more quickly since they are less likely to be invaded through cultural interaction with other regions or mutation. Consequently, the regions with higher SL levels outperform those with lower SL levels. Also, those regions which act selfishly by only sharing resources within the region (SSL = 3) outperform those regions that allow resources to be shared with other regions. Eventually, (usually within about 1500 cycles) the grid becomes dominated by a single region composed of cells which share all their resources (SL = 4) with those holding identical cultural attributes (SSL = 3). Figure 1 and tables 3 and 4 show a typical simulation run.

Figure 1 & Tables 3 & 4 about here!

### 4.2 Experiment B – Multiple Regions with “In-Group” Sharing

Similar results are obtained as those for experiment A, except that regions form more quickly but don’t break down so easily. Because the “genetic” style of evolution can only replicate information when cells die, this means that barriers to resource sharing, which are created by the C meme, persist and reduce the optimality of the population. Figure 2 shows a typical simulation run.

### 4.3 Experiment C – The Majority Benefits At Minorities Expense Through Strong Altruism

When resources are awarded only to selected cells (only those cells with even row and column addresses), this does not select for selfish cell resource behaviour as might be assumed. Ironically, those cells which actually receive the resources give them all to their neighbours, thus “starving” themselves. The cultural evolutionary process selects for strong altruism. This may initially appear to be counter intuitive, since a cell which is starved of resources is more likely to mutate or take on new memes. However, if such a cell is surrounded by cells with high values for SL, they will tended to continually re-propagate these high SL values to the altruistic cell. The majority “unproductive” cells in the Moore neighbourhood, benefit at the expense of the minority cells. By becoming “repositories” of altruistic memes the majority cells, via social influence, keep the minority “productive” cells altruistic. Figure 3 shows a typical simulation run.

### 4.4 Experiment D – Altruism Hampered By Boundaries

Although strong altruism is selected for in the majority of cells, it is hampered by the lack of cell homogeneity. Also a significant minority of cells are less “altruistic” sharing only some of any resource reward. Figure 4 shows a typical simulation run.

Figures 2,3,4 about here!

## 5. Observations

### 5.1 Cultural Groups and In-Group Bias

Regions of shared cultural attributes can be seen as cultural groups. It should be noted that under cultural evolution (experiments A and C) these groupings emerge from the propagation of individual attributes which are initially set to arbitrary values. The mechanisms by which groups become successful (outperforming other groups) involves maximum in-group sharing and minimum out-group sharing. This appears as the emergence of an artificial form of "in-group bias", a phenomena which pervades most real social systems (Kramer & Brewer 1984). Ironically, this process which quickly produces sharing behaviour can become an obstacle later when the population is composed of several competing groupings.

### 5.2 Reciprocal OR Real Altruism?

Can the sharing behaviour that emerges in the above experiments be viewed as altruism? The sharing that does emerge is always strictly within the group. In this sense it could be argued that the sharing behaviour is a form of reciprocal altruism since sharing within a group, by definition, means that those other members may reciprocate in the future (since a group is defined as those with the same memes and hence sharing behaviours). However, in experiments C and D where resources were never awarded to some designated cells (unproductive cells), sharing still emerged. This kind of altruism emerges because individual cells can't distinguish between those that acquire resources and those that don't. Never-the-less, the experiments demonstrate that individual satisficing learning rules, via social influence, can produce altruistic behaviours.

### 5.3 Tags and Group Conflict

The C meme used in the experiments has no direct behavioural impact (a tag). Cultural groupings tend to form which are distinguished purely by different values of the tag attribute. It would seem that the more values a tag could take, the more groups would form, which would increase the time required for a single group to dominate the population due to the increase in inter-group conflict. This may not however, be the case when the number of tags are increased (see Axelrod 1995).

### 5.4 "Genetic" v. Cultural Evolution

The “genetic” experiments B, D produced similar results initially when resources were distributed equally (experiments A and B) but failed to become dominated by a single group. This results from the reduced communication of attribute information, since this only occurs when a cell on a group boundary "dies" by reaching an EL of zero. Also, copying of attribute information (reproduction) implies mutation, which was here set at a fairly high level. With sparse rewards the process is exaggerated, such that in experiment D a major difference is observed between the optimality of the resource distribution in comparison with experiment C.

## 6 Conclusions and Future Work

The experiments presented here, demonstrate that group selection can operate on groups created via social influence to produce altruistic behaviour (as speculated, but not demonstrated, by Pedone & Parisi 1997). Moreover, it has been demonstrated that in the simple scenarios presented, a genetic method of evolution produces less optimal results than a memetic method.

This form of cultural evolution is offered as a unified approach to the study of group formation, cultural evolution, cooperation and altruism. Memes are viewed as the basic replicators upon which societies are constructed. The memetic approach is inherently distributed and dynamic, offering the future possibility of application to areas such as collective robotics and software agent co-ordination when highly changeable and dynamic environments demand unsupervised, self-organising and socially oriented solutions.

The SS model presented here is purposefully simplistic. It is an initial attempt to capture some aspects of cultural evolution and apply them in a productive way. In keeping with the KISS (Axelrod 1997) principle it tries to capture the process under investigation at the simplest possible level. One powerful aspect of cultural evolution which is missing from the model is the process of specialisation. Future work will attempt to explore minimal mechanisms that allow for the productive emergence of specialisation within and between groups. Also, a relaxation of the "cultural closeness" metric allowing for a more realistic case of "hidden memes" will be explored. This line of enquiry offers the potential to forge links with work already done using tags or labels (Holland 1993, Riolo 1997) and richer models of social selection (Simon 1990).

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| Description | Tng | Zng | Mng | CZng |
|---|---|---|---|---|
| Exp.A - “cultural” evolution | 2631 | 15 | 116 | 4843 |
| Exp.B - “genetic” evolution | 2520 | 22 | 109 | 5221 |
| Exp.C - “cultural” evolution with sparse rewards | 2486 | 42 | 134 | 10532 |
| Exp.D - “genetic” evolution with sparse rewards | 1854 | 79 | 69 | 18804 |

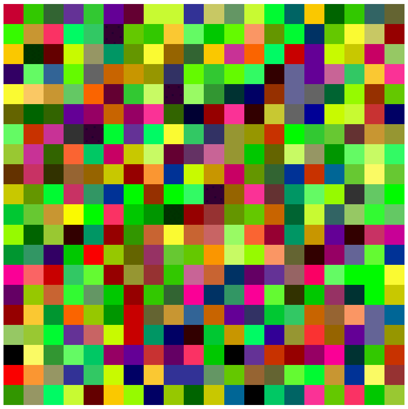
**Table 1 - Energy Levels and Optimality**

This table shows the averaged results of 100 simulation runs for each experiment. In all cases each individual simulation run was terminated after cycle 2000. The Tng column shows the sum of all the energy in all the cells of the population, Zng shows the number of cells with a zero energy level (which might be considered as “dead” cells), Mng shows the number of cells with the maximum energy level (i.e. 9 energy points) and CZng shows the cumulative number of zero energy cells observed over the entire run (all 2000 cycles with a count of zero energy cells collected every 10 cycles). CZng is intended to give a measure of the optimality of the system over the entire run, whereas the other statistics give only a snapshot of the system at the end of the run (cycle 2000).

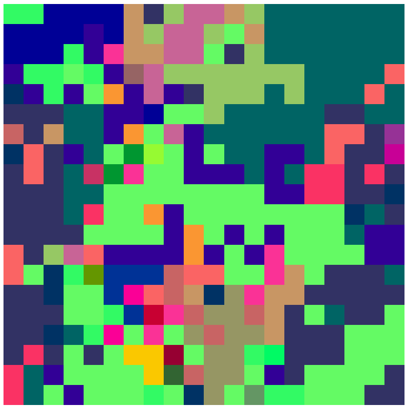
| Meme | SL | | | | | C | | | | | SSL | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Value | 0 | 1 | 2 | 3 | 4 | 0 | 1 | 2 | 3 | 4 | 0 | 1 | 2 | 3 | 4 |
| Exp.A | 0 | 0 | 0 | 4 | 396 | 90 | 65 | 65 | 74 | 107 | 0 | 0 | 0 | 400 | 0 |
| Exp.B | 0 | 0 | 0 | 6 | 394 | 107 | 63 | 65 | 55 | 110 | 0 | 0 | 1 | 399 | 0 |
| Exp.C | 0 | 0 | 1 | 14 | 386 | 140 | 54 | 49 | 53 | 104 | 0 | 0 | 0 | 400 | 0 |
| Exp.D | 0 | 0 | 6 | 78 | 316 | 75 | 87 | 90 | 83 | 66 | 0 | 0 | 1 | 398 | 1 |

**Table 2 - Meme Values**

Here the averages of the distributions of meme values are shown. For each experiment 100 simulation runs were performed. Each run was terminated after cycle 2000. The averages are calculated from the distributions of memes at termination. Notice that in all simulation runs, SSL=3 is strongly selected for (indicating sharing with identical “cultures” or “meme bundles”). SL=4 is also selected for (indicating full sharing of resource rewards). Notice however that the “genetic” style of evolution (experiment D) provides niches for less altruistic sharing behaviours with over 20% of cells not sharing all their resources.



Cycle 0



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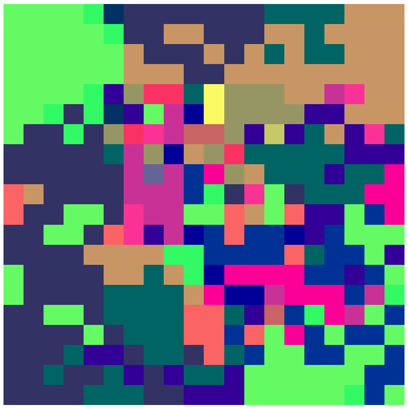

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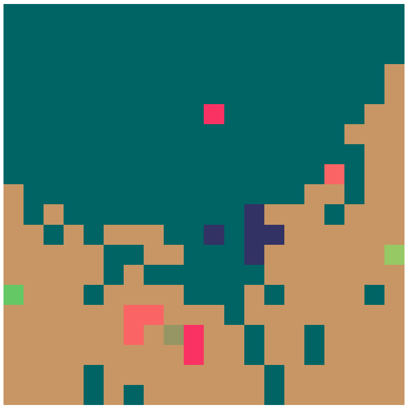

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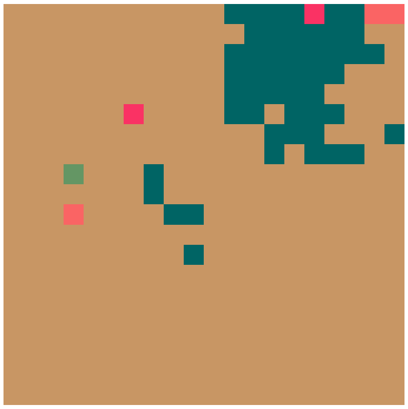

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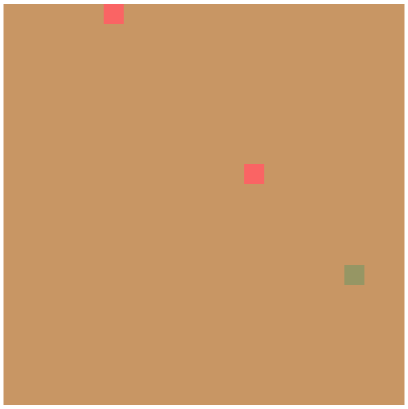
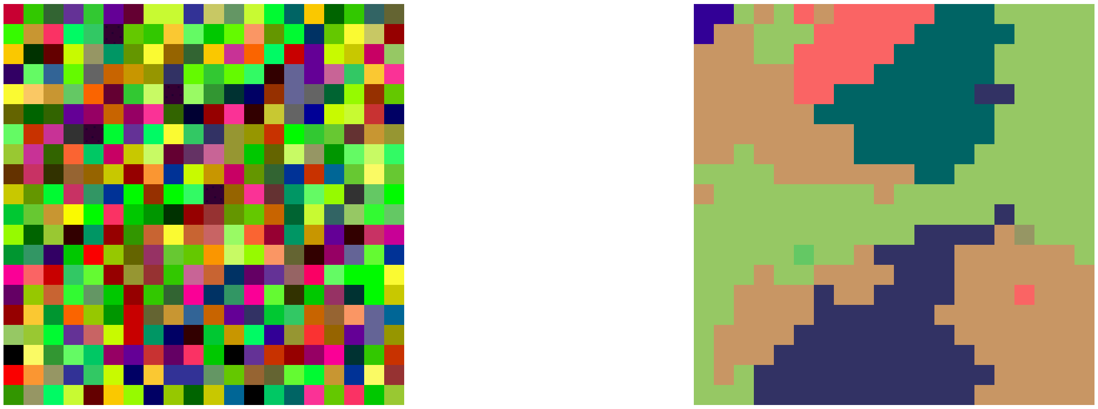


Cycle 1500

***Figure 1***

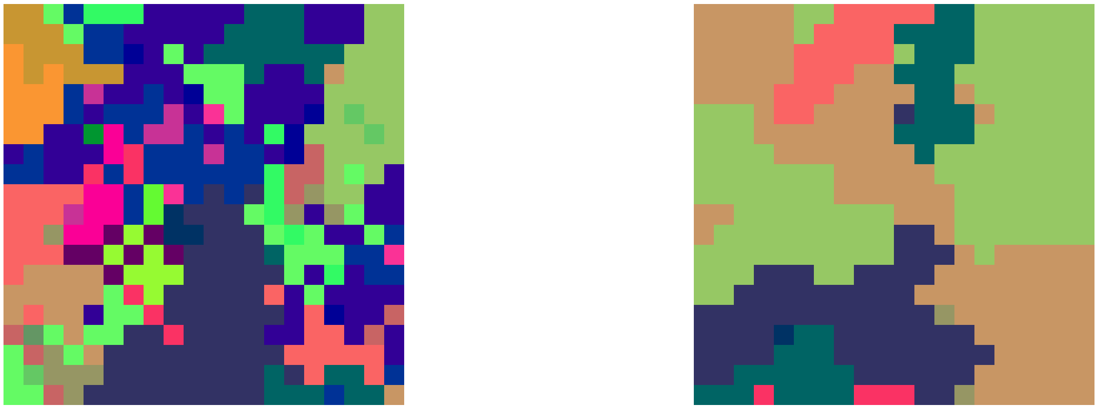
***Experiment A - Example of A Typical Run.***

*A simple "cultural" evolutionary process produces maximum resource sharing behaviour. The colour of each cell represents the values of the three memes held. Notice the formation of spatial regions with shared meme bundles and the scattered "mutant" cells. By cycle 1500 most of the grid is occupied by a single meme bundle. The continuing existence of mutant cells is a result of the scenario - which tends to "starve" some cells because energy is distributed uniformly but stochastically. Cells from the dominant "culture" resist invasion by sharing resources with each other but not the mutant cells.*



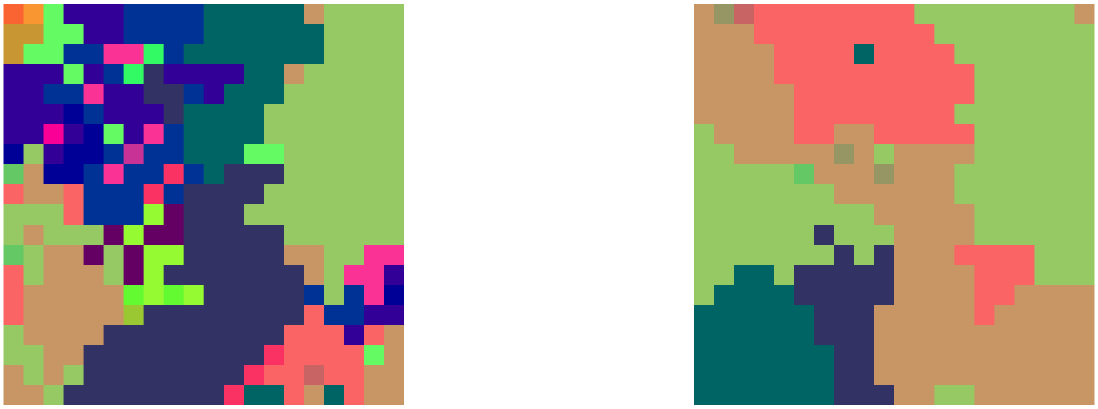
Cycle 0

Cycle 500



Cycle 100

Cycle 1000



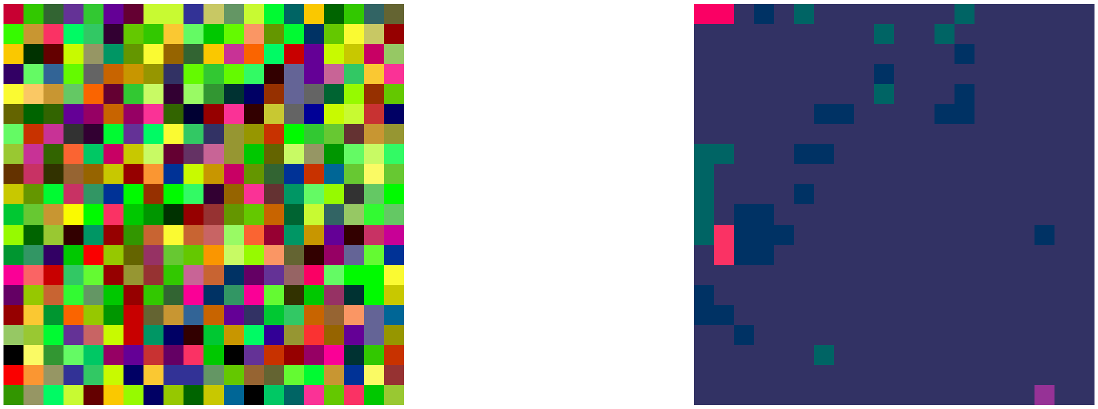
Cycle 200

Cycle 1500

***Figure 2***

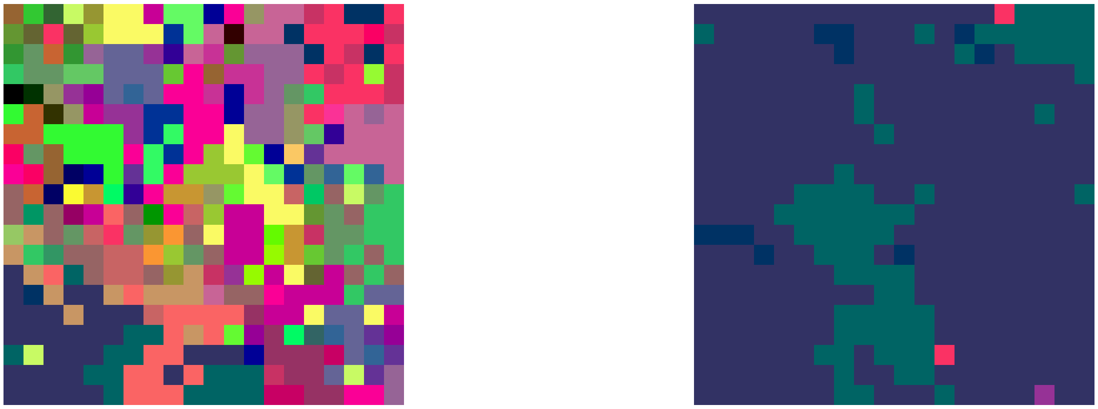
***Experiment B - Example of A Typical Run.***

*Here an asexual form of "genetic" evolution is used in place of the "cultural" evolutionary process. The colour of each cell represents the values of the three memes held. Notice the formation of spatial regions with shared memes. These regions form more quickly than in Experiment A, but once formed tend not to break down.*



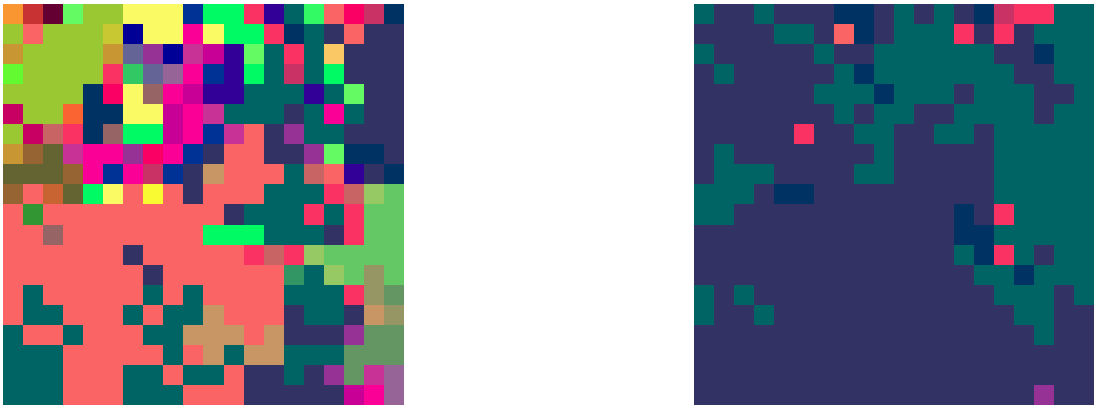
Cycle 0

Cycle 500



Cycle 100

Cycle 1000



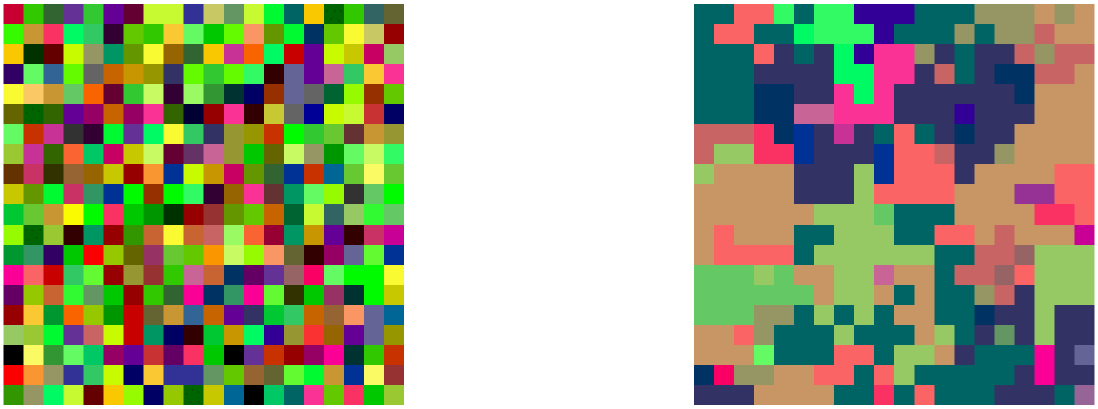
Cycle 200

Cycle 1500

***Figure 3***

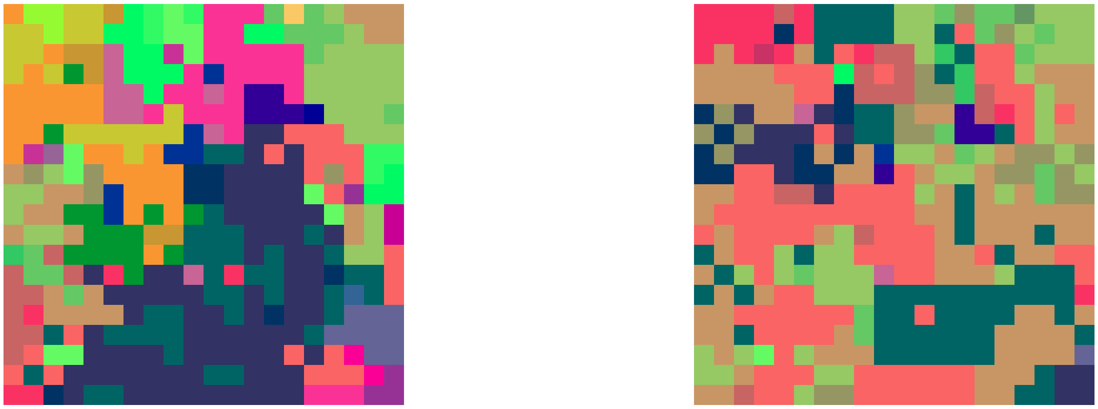
***Experiment C - Example of A Typical Run.***

*When resources are awarded only to selected cells (only those cells with even row and column addresses), this does not select for selfish cell resource behaviour as might be assumed. Ironically, those cells which actually receive the resources give all to their neighbours, thus "starving" themselves. The cultural evolutionary process selects for strong altruism. Also, note that there is a more rapid domination of the population by a single "culture" (compared with figure 1) but there is more tendency to drift in the C meme.*



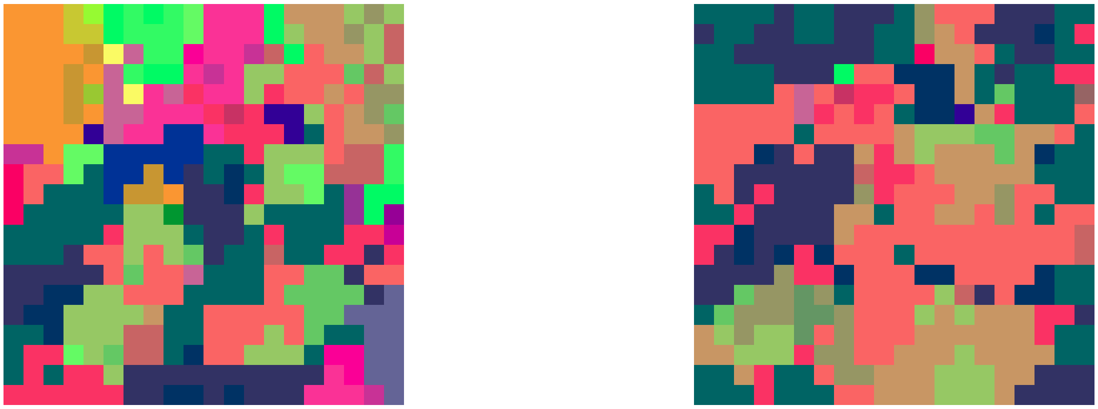
Cycle 0

Cycle 500



Cycle 100

Cycle 1000



Cycle 200

Cycle 1500

***Figure 4***
***Experiment D - Example of A Typical Run.***
*Resources are awarded only to selected cells (only those cells with even row and column addresses), and a "genetic" style of evolutionary process is used in place of the "cultural" process shown in figure 3. Diversity is high. Although cell altruism is selected for in the majority of cells, it is hampered by the lack of homogeneity. Also a significant minority of cells are less "altruistic" sharing only some of their resource reward.*

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0315 | 0010 | 4415 | 1349 | 1227 | 0243 | 3212 | 0427 | 0421 | 0342 | 0046 | 2333 | 0421 | 1327 | 4138 | 4012 | 2205 | 0019 | 0232 | 0028 |
| 1113 | 3127 | 3130 | 2046 | 2439 | 2210 | 1013 | 0016 | 0327 | 4047 | 4402 | 2110 | 0435 | 0407 | 1323 | 3030 | 1018 | 1429 | 0045 | 3002 |
| 4011 | 1100 | 2001 | 4112 | 3330 | 0331 | 0402 | 1429 | 0305 | 4411 | 4018 | 3341 | 2303 | 2048 | 4007 | 0248 | 4117 | 3016 | 1033 | 4436 |
| 3422 | 4040 | 1449 | 2118 | 1235 | 1308 | 2409 | 1407 | 4031 | 2112 | 1228 | 2111 | 3045 | 1004 | 2448 | 0247 | 4448 | 2434 | 0329 | 4341 |
| 1426 | 1041 | 3122 | 3430 | 2308 | 3215 | 1225 | 1142 | 2214 | 0142 | 0127 | 2311 | 2426 | 4100 | 2440 | 1236 | 3412 | 3118 | 4103 | 1011 |
| 4201 | 2203 | 3200 | 0243 | 0037 | 1304 | 0037 | 4348 | 3205 | 1218 | 3008 | 4345 | 1006 | 4227 | 1234 | 3146 | 4113 | 0428 | 1413 | 2421 |
| 4047 | 0206 | 3343 | 3318 | 2216 | 1322 | 1345 | 2046 | 1420 | 2438 | 4032 | 2121 | 1404 | 0201 | 0113 | 1223 | 2220 | 4310 | 3128 | 2121 |
| 3226 | 3342 | 3204 | 3027 | 1434 | 1034 | 3015 | 1141 | 3213 | 0130 | 4443 | 2126 | 4407 | 4209 | 1143 | 3334 | 3300 | 4044 | 1149 | 3049 |
| 3107 | 2136 | 2108 | 1026 | 0305 | 3013 | 3004 | 4129 | 4246 | 4114 | 2404 | 1032 | 0408 | 4410 | 4243 | 0206 | 0444 | 2226 | 2147 | 2227 |
| 3018 | 0409 | 1327 | 2134 | 1338 | 4247 | 0119 | 4101 | 0119 | 3042 | 2214 | 0309 | 4340 | 4319 | 0330 | 4046 | 3117 | 3316 | 3431 | 0112 |
| 0220 | 2229 | 3123 | 0211 | 0111 | 3137 | 4404 | 3307 | 1109 | 3005 | 0419 | 0407 | 1014 | 1302 | 3411 | 0429 | 0238 | 4439 | 2321 | 3430 |
| 3112 | 2207 | 3227 | 1002 | 0332 | 3000 | 4301 | 2026 | 1425 | 2022 | 3231 | 0148 | 3026 | 4214 | 0336 | 2400 | 0249 | 1008 | 2135 | 2243 |
| 4022 | 1331 | 3422 | 4406 | 0103 | 2011 | 4203 | 1139 | 2225 | 1015 | 3402 | 1145 | 3115 | 0430 | 0028 | 1005 | 0037 | 2442 | 3329 | 4246 |
| 3243 | 4238 | 4004 | 2434 | 3328 | 3005 | 2122 | 0419 | 0016 | 4440 | 2027 | 3038 | 4422 | 1343 | 2234 | 2033 | 4044 | 0117 | 0111 | 1421 |
| 4426 | 2011 | 2028 | 2328 | 2339 | 4400 | 3009 | 0011 | 4415 | 3244 | 3035 | 1333 | 3241 | 3320 | 2109 | 4401 | 1138 | 2316 | 0113 | 3019 |
| 3000 | 0324 | 4028 | 2303 | 2019 | 3302 | 4001 | 0020 | 3121 | 1447 | 1305 | 0247 | 4034 | 0225 | 2438 | 1303 | 1021 | 0430 | 2441 | 0446 |
| 4435 | 3220 | 1329 | 1344 | 3231 | 4115 | 4001 | 0334 | 2429 | 1008 | 0223 | 2407 | 2041 | 4140 | 2122 | 2410 | 0300 | 0244 | 2449 | 1407 |
| 0001 | 2145 | 0129 | 4044 | 1432 | 0037 | 0242 | 1416 | 4429 | 3139 | 4409 | 0005 | 1348 | 0203 | 3009 | 0031 | 3247 | 2319 | 0014 | 0208 |
| 0106 | 4123 | 3335 | 0343 | 2436 | 4110 | 2427 | 0329 | 0340 | 0348 | 2334 | 1013 | 1026 | 0028 | 3325 | 1321 | 3122 | 4249 | 2143 | 0418 |
| 4305 | 3332 | 2042 | 0422 | 2007 | 4017 | 3111 | 2426 | 2015 | 2204 | 3011 | 0445 | 0000 | 1436 | 4135 | 4349 | 1011 | 3131 | 4405 | 3223 |

***Table 3 - Experiment A.***

*The initial random starting values for each cell of the gird (as shown in figure 1, cycle 0). The first 3 digits represent the 3 memes. The final (right-hand) digit represents the cell energy level. The first digit represents the SL (sharing level) which specifies the number of energy points to share with neighbours when an energy reward is received. The third digit represents the SSL (sharing similarity level) which specifies the level of cultural similarity (specified in identical memes) required for a neighbour to be considered for a share of an energy reward. Note that the second digit has no direct behavioural significance.*

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4339 | 4338 | 4337 | 4331 | 4333 | 4230 | 4335 | 4335 | 4336 | 4339 | 4339 | 4338 | 4334 | 4335 | 4337 | 4335 | 4339 | 4336 | 4336 | 4332 |
| 4336 | 4339 | 4338 | 4338 | 4335 | 4338 | 4334 | 4338 | 4338 | 4339 | 4339 | 4337 | 4337 | 4338 | 4339 | 4337 | 4339 | 4339 | 4338 | 4330 |
| 4338 | 4339 | 4339 | 4339 | 4338 | 4339 | 4335 | 4336 | 4338 | 4336 | 4335 | 4338 | 4332 | 4334 | 4333 | 4336 | 4338 | 4338 | 4335 | 4333 |
| 4339 | 4339 | 4339 | 4337 | 4334 | 4339 | 4334 | 4339 | 4339 | 4339 | 4338 | 4339 | 4332 | 4338 | 4338 | 4339 | 4339 | 4339 | 4336 | 4335 |
| 4337 | 4339 | 4339 | 4336 | 4339 | 4338 | 4337 | 4339 | 4336 | 4339 | 4338 | 4336 | 4335 | 4339 | 4339 | 4339 | 4339 | 4339 | 4339 | 4333 |
| 4338 | 4339 | 4339 | 4339 | 4339 | 4339 | 4337 | 4339 | 4338 | 4339 | 4336 | 4339 | 4336 | 4338 | 4339 | 4337 | 4339 | 4338 | 4338 | 4334 |
| 4339 | 4339 | 4339 | 4339 | 4339 | 4339 | 4339 | 4337 | 4338 | 4339 | 4339 | 4334 | 4335 | 4330 | 4337 | 4339 | 4338 | 4339 | 4338 | 4331 |
| 4339 | 4339 | 4339 | 4339 | 4337 | 4339 | 4338 | 4335 | 4338 | 4336 | 4336 | 4336 | 4339 | 4332 | 4335 | 4336 | 4336 | 4330 | 4335 | 4337 |
| 4338 | 4337 | 4339 | 4339 | 4338 | 4337 | 4338 | 4337 | 4337 | 4337 | 4339 | 4336 | 4230 | 4335 | 4332 | 4330 | 4335 | 4336 | 4336 | 4334 |
| 4339 | 4339 | 4339 | 4339 | 4339 | 4339 | 4339 | 4338 | 4339 | 4335 | 4339 | 4338 | 4332 | 4330 | 4337 | 4334 | 4332 | 4334 | 4339 | 4336 |
| 4338 | 4338 | 4339 | 4339 | 4339 | 4338 | 4339 | 4338 | 4339 | 4336 | 4338 | 4338 | 4338 | 4338 | 4338 | 4332 | 4331 | 4330 | 4336 | 4332 |
| 4335 | 4339 | 4339 | 4336 | 4338 | 4339 | 4338 | 4339 | 4338 | 4339 | 4339 | 4338 | 4331 | 4334 | 4338 | 4339 | 4336 | 4331 | 4335 | 4331 |
| 4336 | 4338 | 4337 | 4338 | 4334 | 4338 | 4339 | 4337 | 4338 | 4339 | 4339 | 4339 | 4334 | 4330 | 4337 | 4332 | 4335 | 4333 | 4336 | 4334 |
| 4335 | 4339 | 4338 | 4339 | 4336 | 4337 | 4334 | 4339 | 4335 | 4339 | 4338 | 4334 | 4338 | 4332 | 4338 | 4335 | 4335 | 3330 | 4337 | 4330 |
| 4336 | 4337 | 4333 | 4330 | 4330 | 4330 | 4332 | 4337 | 4334 | 4337 | 4337 | 4331 | 4334 | 4335 | 4333 | 4338 | 4338 | 4331 | 4335 | 4330 |
| 4335 | 4339 | 4336 | 4339 | 4334 | 4338 | 4334 | 4333 | 4337 | 4332 | 4337 | 4332 | 4336 | 4337 | 4334 | 4336 | 4331 | 4337 | 4339 | 4331 |
| 4335 | 4335 | 4336 | 4338 | 4333 | 4330 | 4338 | 4335 | 4339 | 4337 | 4335 | 4338 | 4337 | 4339 | 4337 | 4339 | 4336 | 4339 | 4339 | 4338 |
| 4337 | 4333 | 4339 | 4336 | 4337 | 4338 | 4332 | 4338 | 4337 | 4331 | 4337 | 4334 | 4338 | 4337 | 4334 | 4339 | 4334 | 4335 | 4339 | 4339 |
| 4338 | 4339 | 4337 | 4338 | 4338 | 4338 | 4337 | 4337 | 4337 | 4338 | 4339 | 4330 | 4337 | 4334 | 4335 | 4336 | 4335 | 4339 | 4338 | 4334 |
| 4338 | 4336 | 4338 | 4337 | 4337 | 4330 | 4338 | 4330 | 4335 | 4339 | 4337 | 4335 | 4335 | 4332 | 4337 | 4335 | 4330 | 4331 | 4333 | 4330 |

***Table 4 - Experiment A.***

*The values for each cell of the grid by cycle 1500 (as shown in figure 1, cycle 1500). The dominant meme bundle or "culture" is 433. This indicates that all resources are shared with neighbours (SL=4) and that neighbours receive a share of a resource only if they share all 3 memes with the sharing cell (SSL=3). This means that 433 cells only share resources with other 433 cells thus avoiding invasion by mutant "cultures". The culture is "selfish" in the sense that it only shares resources with itself but the individual cells are "altruistic" since all resources are shared with culturally identical neighbours.*