Chapter 5

Group Formation and Agent Altruism

In this chapter a simple form of cultural learning based on satisficing agents is applied to a resource sharing scenario: The SwapShop. Agents are represented as cells on a two dimensional grid which selectively replicate and repel memes to and from neighbours. The memes represent culturally learned traits [7] but also influence resource sharing behaviours. It is demonstrated that a simple cultural learning rule based on an agent satisfaction threshold (rather than an optimising rule) produces agent altruism and promotes group formation. Although such mechanisms have been advanced theoretically [2] to account for human altruism, they have never previously been demonstrated computationally.

Agent altruism is manifest when designated agents (which are rich in resources) donate resources to agents which can never return the favour. Groups are here defined as spatially connected regions of agents holding identical memes. Memes are culturally transmittable units which determine the behaviour of the agents. The emergence and expansion of these cultural groups over time is evident from visual inspection of the evolution

of the grid.

In the cultural or "memetic" learning experiments, the whole grid is quickly dominated by a single group which behaves altruistically. These results are compared to those produced when a simple optimising or "genetic" learning rule is used. In these latter experiments altruism between agents is less evident. This indicates that a simple satisfaction based cultural learning rule is sufficient to produce altruistic behaviour between agents. Moreover, such a rule produces SwapShop societies that are marginally more optimal than an optimising "genetic" learning rule.

However, altruism is only manifest between agents within the same group for both styles of learning rule. This indicates that a form of inclusive fitness or "kin altruism" is occurring [79]. In the memetic form of learning it is therefore demonstrated that the cultural learning rule is sufficient to produce groups which may be viewed as "memetic kin". The agents behave altruistically because this is in the selfish interests of the memes they share.

In the following sections of this chapter, the SwapShop model and a set of experiments are described along with results and analysis.

5.1 The SwapShop Artificial Society

The SwapShop (SS) is a Cellular Automata (CA) model composed of a fixed grid of cells. The framework of the SS is modelled after the Axelrod Cultural Model (ACM) [7]. ACM was used to investigate the emergence of spatial regions of shared "cultural attributes". The model utilises simple attribute propagation rules. Of primary importance in ACM is the concept of "cultural distance". The assumption is that "culturally distant" individuals do not culturally interact. This is expressed in the rule that attribute propagation only takes place between cells that 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 that influence the behaviour of host cells.

The SS captures the salient features of the following scenario: consider a set of agents that need to consume energy to survive. Each inhabits a patch of territory which supplies energy in a probabilistic way. This could be from catching prey or other opportunistic resource gathering. The agents might be interpreted as individual, or small tribes of, humans. The agents have a maximum energy level beyond which they cannot utilise the surplus. The justification for this can be given in the context of catching prey: the energy supplied by the patch is perishable and there is only so much of the prey that can be consumed over a given period of time. The possibility of long term storage techniques is discounted in this scenario. An agent which has reached its maximum energy level is satiated or "satisfied". When energy is supplied by the patch the agent may make resource gifts of energy to neighbouring patches containing agents that are not satisfied (needy neighbours). The amount of resources donated to needy neighbours (if any) is determined by a cultural attribute the agent holds (see below).

Agents store (or host) three cultural attributes (memes). Memes are propagated between neighbours and sometimes mutated by agents. This process attempts to capture a simple form of cultural learning. Agents occasionally culturally interact with their neighbours. Cultural interaction involves an agent and a randomly selected neighbour harmonising memes in the following way: if the two agents have no memes in common then no harmonisation takes place. This assumption (as used by Axelrod in ACM) indicates that agents that are culturally very different do not culturally harmonise. However, if the agents have at least one meme in common then the neighbour will attempt to propagate a differing meme (assuming one exists) to the agent. Additionally agents which are satisfied (i.e.

have the maximum amount of energy) will repel any propagated memes from neighbours. Also agents which are "dead" (i.e. have no energy at all) are not permitted to propagate memes. These restrictions on meme propagation capture the notion that satisfied agents have nothing to learn from others since they are achieving maximal performance and that dead agents have nothing to teach to others since they are in a state of famine.

Agents decide how much energy (if any) to give to needy neighbours based on the "sharing level" (SL) meme that they host. The higher the SL meme, the more energy is shared among needy neighbours. For a needy neighbour to qualify for a resource gift the donating agent compares the "cultural similarly" of a needy neighbour to itself and only makes a resource gift if the neighbour is similar enough. The required level of similarity is mediated by a sharing similarity level (SSL) meme. The higher the SSL meme the more culturally similar a needy neighbour has to be to receive a resource gift. Cultural similarity is measured as the number of cultural attributes (or memes) that two agents share. An agent hosting an SSL meme of zero will make energy gifts to *any* needy neighbour. But if the SSL=3 then the agent will only make gifts to agents who are *culturally identical* (share all three memes).

To summarise, the SS minimally captures a scenario in which boundedly rational satisficers[1] culturally learn behaviours (memes) from neighbours and have the ability to share resources with neighbours in a culturally discriminatory way. That ability is mediated by the memes held by agents. In the following sections a more precise description of the SS model is given.

[1]By "boundedly rational satisficers" is meant that agents use heuristics in an attempt to achieve a satisfactory level of utility.

5.1.1 Cells And Memes

The SS comprises a 20x20 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 to other cells and mutated. The values of the state associated 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. Indirectly however, the C meme may affect resource sharing behaviour since two cells which have different C memes would not be considered identical (i.e. the maximum similarity possible would be 2). This may affect resource sharing behaviour between two cells with different C memes.

5.1.2 Events And Behaviours

During execution of the SS one of three events can occur: life tax, resource reward and cultural interaction. The model is asynchronous avoiding possible artefacts. A synchronous model would update the grid of cells in a time ordered way: applying a life tax to each cell then awarding resources to each cell and then applying the sharing behaviour to each cell for example. Asynchronous updating involves selecting and updating cells in an unordered (pseudorandom) way. Synchronous updating has been shown to produce results which do not occur when asynchronous updating is used [67], [93]. Since the SwapShop model attempts to capture a process involving independently acting agents with no central control an asynchronous updating procedure was adopted.

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 (the intuition being that a poorly performing cell change its behaviour). A resource reward event involves a cell being awarded 4 energy points (a value significantly less than the maximum allowable EL value - see below). 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 (with replacement) 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 (in this case 64 - since neighbours are selected with replacement the same neighbour make get multiple donations). The remaining energy points are then added to the agent's own energy level up to a maximum of 9. The maximum of 9 was chosen so that cells cannot store large quantities of energy. Any surplus beyond this is considered to have perished. 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 (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 its memes whereas an unsatisfied or dead cell cannot propagate memes.

Neighbours are defined as the eight cells surrounding a cell (the so-called Moore neighbourhood [67]). The edges of the SS are not wrapped into a torus, cells at edges therefore, do not have a full complement of neighbours. This arrangement allows for easier visual identification of spatial regions of connected cells hosting the same memes (see section

5.3 below)[2].

5.1.3 The System Cycle

A single cycle of the system is implemented as:

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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
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Mutation involves increasing or decreasing (with equal probability) a meme value by one. Values out of range are reset to the nearest value in range.

5.2 Four Experimental Scenarios in the SwapShop

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

[2]This arrangement could effect the evolution of groups and it would be of interest to compare the results obtained here with a toroidal topology.

5.2.1 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). Specifically a cell is 4 times more likely to receive a life tax event (where it loses one energy point) than a resource reward event (where it receives 4 energy points). This captures the notion that cells consume energy at a constant a low level but replenish it less often.

Initially each cell in the grid is initialised with pseudo-random values (uniformally selected from the associated range) for each meme and EL level.

5.2.2 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. If more than one neighbour shares the same highest EL value then a random selection is made. This implements a form of local asexual evolution where fitness is based on EL. In this scenario the memes can be viewed as "genes". This allows for a comparison to be made between a cultural and genetic style of evolution.

5.2.3 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 therefore cannot benefit from sharing by others. Note that the same amount of energy is awarded to the grid as a whole but it is only provided to those cells with even row and column addresses.

5.2.4 Scenario D - "Genetic" Evolution With Sparse Rewards

The same settings as scenario C (above) are used, but the "genetic" style of evolution was used as in scenario B (above).

5.3 Results

For each scenario an experiment involving 100 individual simulation runs was executed with a different initial pseudo-random number seed for each run. The meme values and EL value for each cell were initialised randomly from a uniform distribution over their associated ranges. For each experiment the system cycle was iterated 2000 times. Experiments indicated that beyond this no significant changes occurred (up to 20,000 cycles). Tables 5.1 and 5.2 show a synthesis of all the runs for each experiment. Table 5.1 shows the averaged results of 100 simulation runs for each experiment. The Tng column shows the sum of all the energy in all the cells of the population at cycle 2000, Zng shows the number of cells with a zero energy level (dead cells) at cycle 2000, Mng shows the number of cells with the maximum energy level (i.e. 9 energy points) at cycle 2000. 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 in terms of preventing cells from reaching zero energy. The other statistics give only a snapshot of the system at the end of the run

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 5.1: Energy levels and optimality measures for four experiments in the SwapShop. See section 5.3 for an explantion of the measures.

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 5.2: Meme value distributions for four experiments in the SwapShop. See section 5.3 for an explanation of the values given.

(cycle 2000). Figures 5.1 and 5.2 show a representation of these measures, table 5.2 shows averages of the distributions of meme values (over the 100 simulation runs) at cycle 2000.

Given the above results, notice that in all simulation runs, SSL=3 is strongly selected for. This indicates sharing with neighbours possessing identical memes only. This follows from Allison's theory [2] that altruism can be selected for between individuals who share the same memes. Essentially, the memes are acting selfishly by inducing agents to share resources between those hosting the same memes. Unconditional sharing (SSL=0) is not selected for since this would allow for agents with different memes from the unconditional sharing agent to benefit. It is shown also that SL=4 is selected for. This indicates full sharing of resource rewards: all resources awarded to an agent are first offered to needy neighbours (if they exist). 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.

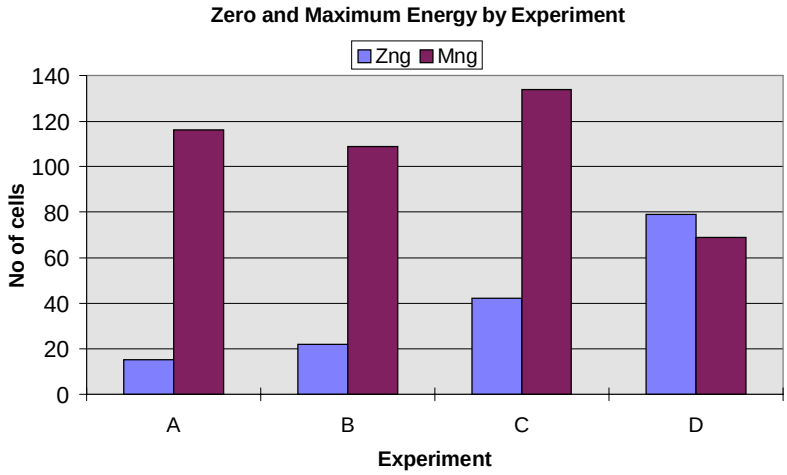

Figure 5.1: Zero and maximum energy levels for four experiments. Values are plotted from table 5.1. See section 5.3 for an explantion of the measures.

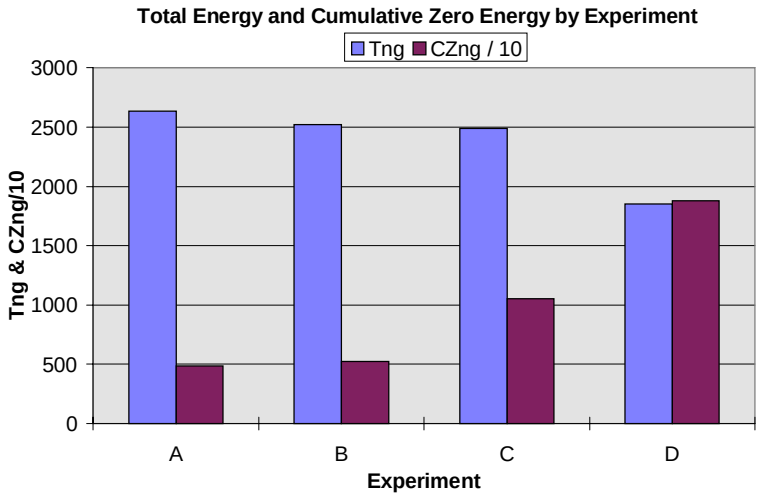

Figure 5.2: Total energy and cumulative energy for four experiments. Values are plotted from table 5.1. See section 5.3 for an explantion of the measures.

5.3.1 Results of Experiment A - Single Region with Total Sharing

Within a few hundred cycles spatial regions of agents sharing the same memes emerge (cultural groupings). 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 groups or mutation. Consequently, the groups with higher SL levels perform better than those with lower SL levels. Those groups which act selfishly towards the out-group by only sharing resources with those agents in the in-group (SSL = 3), also do better than those regions that allow resources to be shared with other groups (SSL < 3). 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 memes (SSL = 3). Figure 5.3 shows a typical simulation run. Figures 5.7 and 5.8 show the values of the state variables in each cell for cycle zero and cycle 2000 respectively.

5.3.2 Results of Experiment B - Multiple Regions with In-Group Sharing

A similar process occurs as that seen in experiment A. However, cultural groups form more quickly and do not break down so easily. Since 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 over that found in experiment A (see table 5.1 and notice lower Tng, Mng and higher Zng and Czng than experiment A). It can be noted however, that the reduction in optimality over experiment A is not of a high degree. Figure 5.4 shows a typical simulation run. It can be deduced that the different groups are created by C meme diversity since the SL and SSL memes converge to 4 and 3 respectively in all simulation runs (see table 5.2).

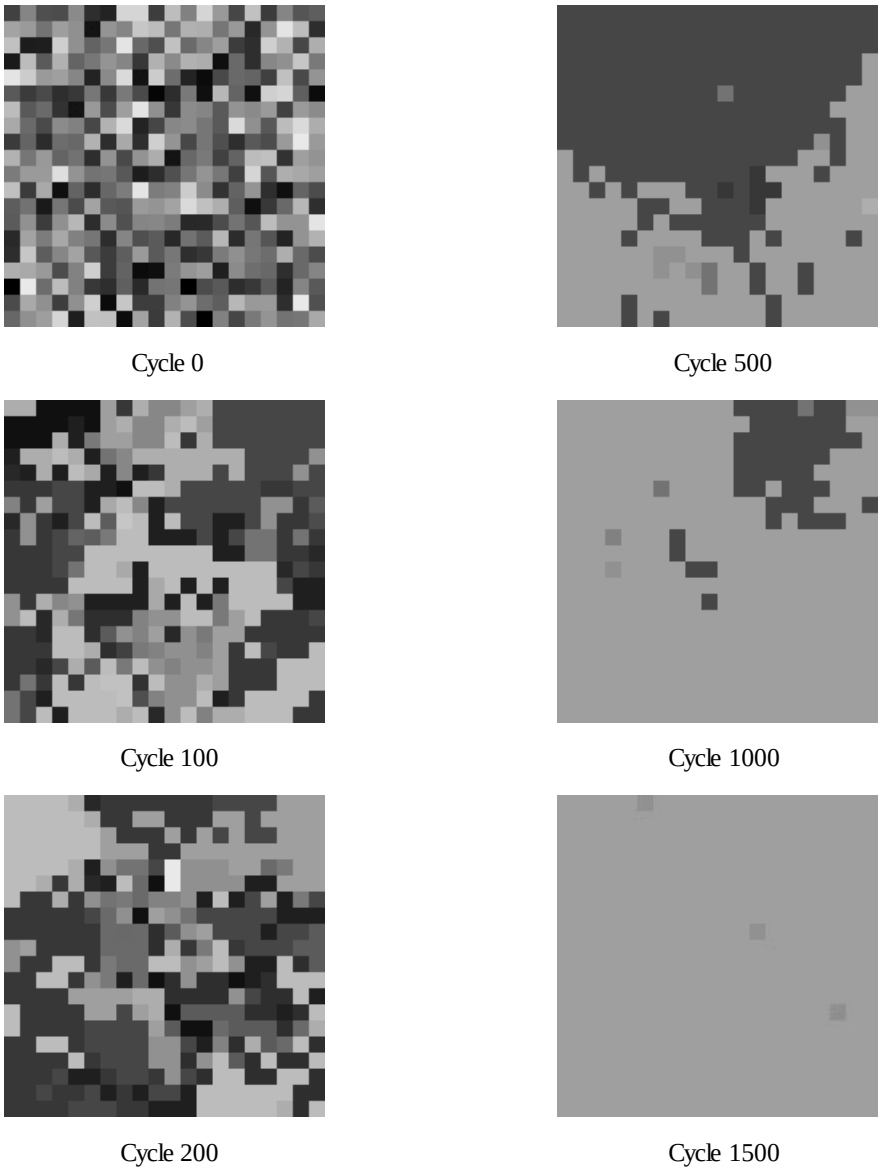

Figure 5.3: Experiment A - example of a typical run. A simple "cultural" evolutionary process produces maximum resource sharing behaviour. The colour of each cell represents the values of the three memes held. Each distinct set of memes is represented by a different colour. Notice the formation of spatial 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.

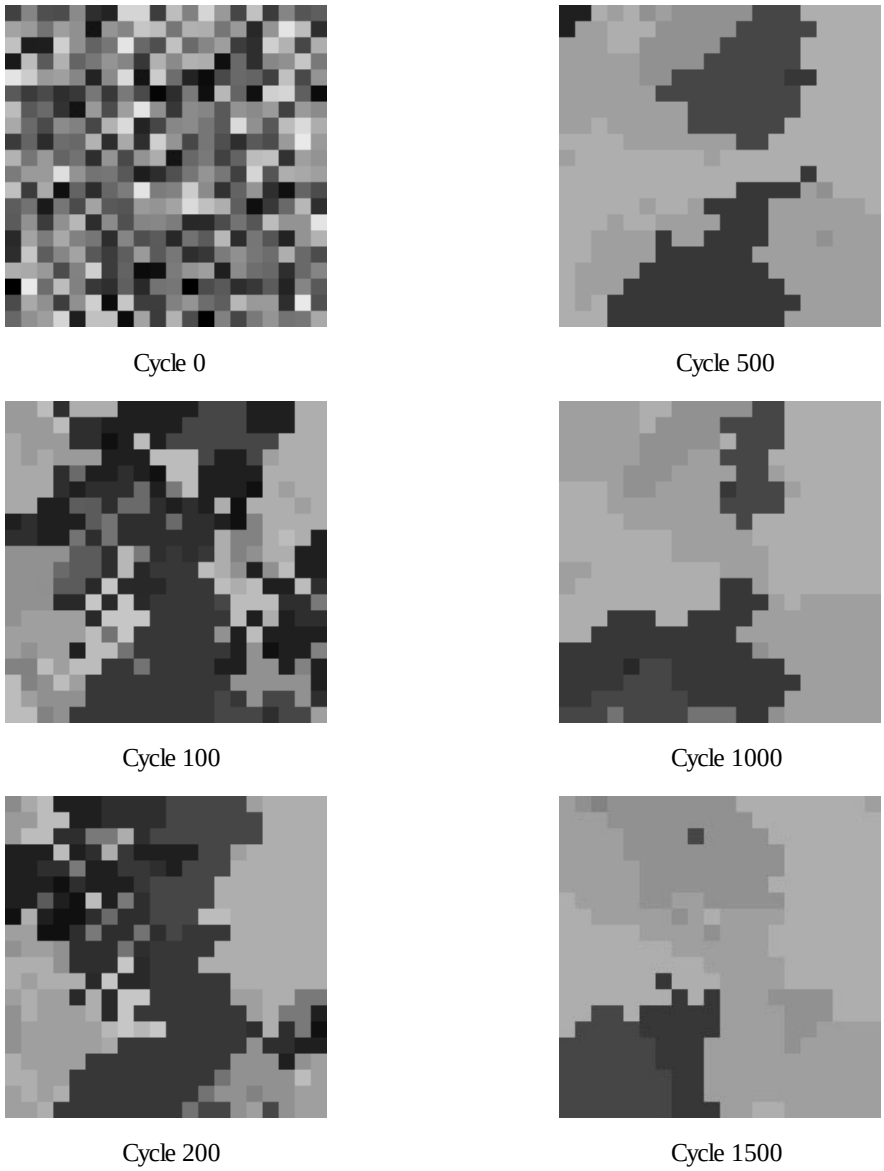

Figure 5.4: Experiment B - example of a typical run. Here an asexual form of "genetic" evolution is used in place of the "cultural" evolutionary process. The colour of each cell represents the values of the three memes held. Each distinct set of memes is represented by a different colour. Notice the formation of spatial regions with shared memes. These regions form more quickly than in Experiment A, but once formed tend not to break down.

5.3.3 Results of Experiment C - The Productive Minority Share All

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 agent level 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 tend to continually re-propagate these high SL values to the starving cell which actually receives the resource rewards. The majority "unproductive" cells in the Moore neighbourhood, benefit at the expense of the minority cells which receive and distribute rewards. By becoming "repositories" of memes which produce altruistic behaviour the majority cells, via social influence, keep the minority "productive" cells behaving altruistically. Figure 5.5 shows a typical simulation run.

5.3.4 Results of Experiment D - Altruism Hampered By Cultural Boundaries

Although strong altruism is selected for in the majority of cells, it is hampered by the lack of cultural homogeneity. Also a significant minority of cells behave less "altruistically" sharing only some of any resource rewarded (as stated above). Over 20% of cells have an SL meme of less than 4 (see table 5.2) . Figure 5.6 shows a typical simulation run.

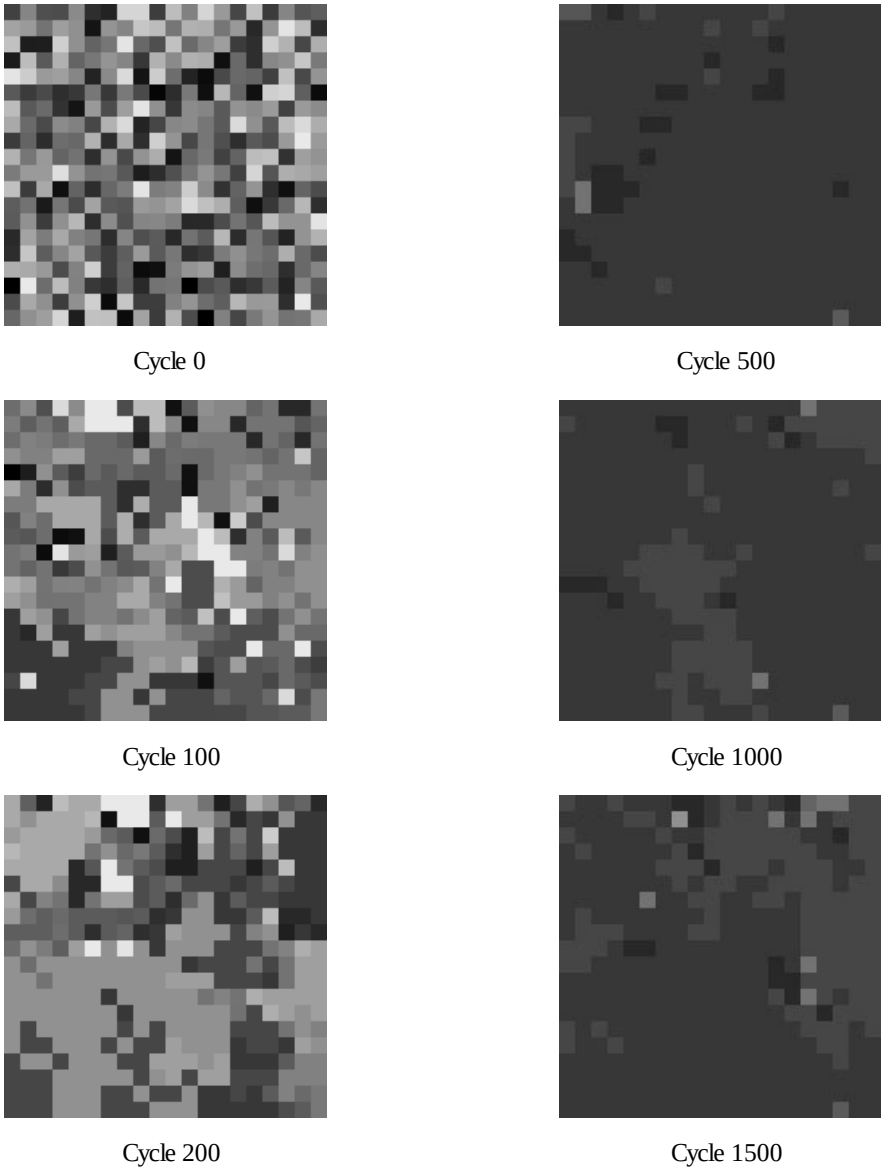

Figure 5.5: Experiment C - example of a typical run. When resources are awarded only to selected cells (only those cells with even row and column addresses), this does not select for selfish cell resource behaviour as might be assumed. Ironically, those cells which actually receive the resources give 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 5.3) but there is more tendency to drift in the C meme.

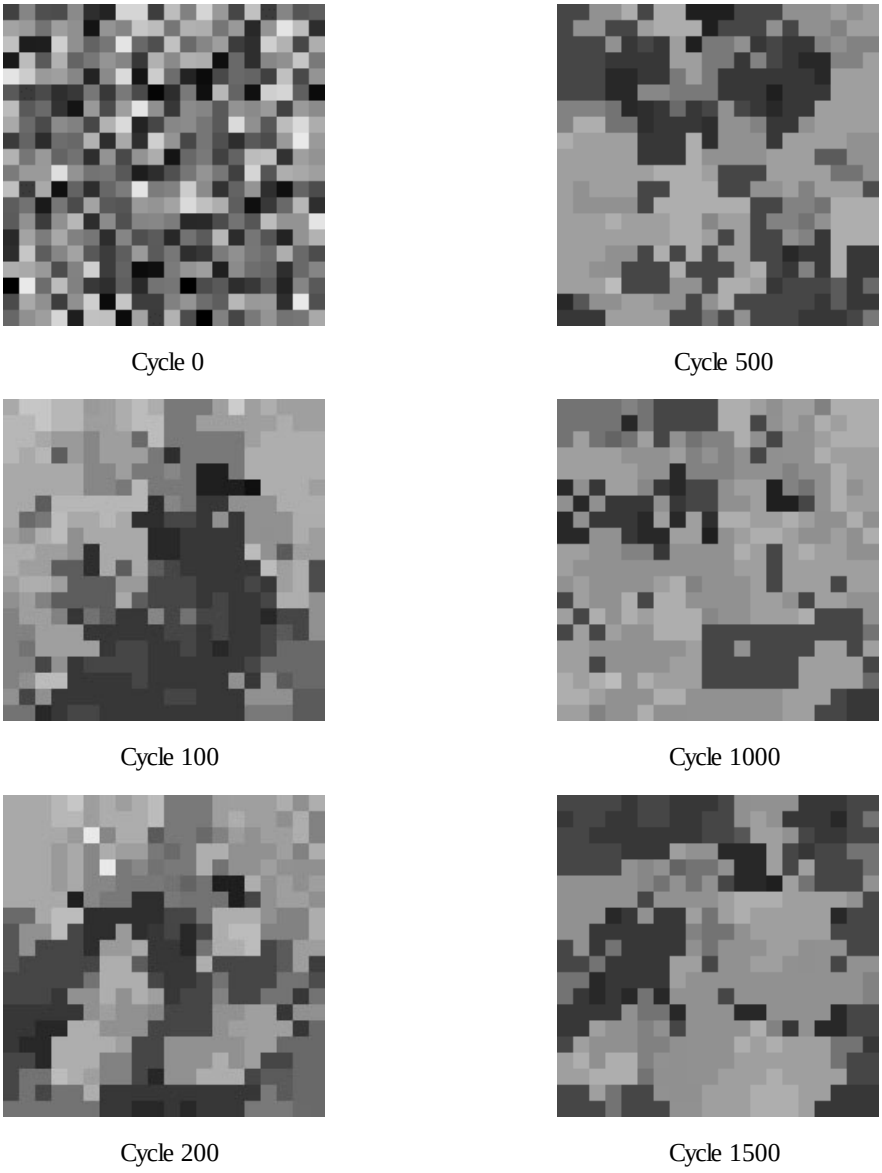

Figure 5.6: Experiment D - example of a typical run. Resources are awarded only to selected cells (only those cells with even row and column addresses), and a "genetic" style of evolutionary process is used in place of the "cultural" process shown in figure 5.5. Diversity is high. Although cell altruism 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.

5.4 Observations

5.4.1 Cultural Groups and In-Group Bias

Regions of shared cultural attributes can be seen as cultural groups. It should be noted that these groupings emerge from the propagation of individual attributes (memes), which are initially set to arbitrary values. The mechanisms by which groups become successful, by 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 [103]. Ironically, this process, which quickly produces sharing behaviour, can become an obstacle later when the population is composed of several competing groupings.

5.4.2 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. 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. However, it can be argued that this is an example of inclusive fitness or "kin altruism". Since agents can recognise and make resource gifts *only to those neighbours who share all the same memes,* the memes (or genes) are inducing altruism between agents for their own selfish interests.

5.4.3 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 is increased (see [7]). This latter possibility is due to the assumption that cultural interaction only takes place between cells sharing at least one identical meme. As the number of tags is increased the probability that two neighbouring cells share at least one meme is also increased. Cultural boundaries are therefore less likely to form.

5.4.4 "Genetic" v. Cultural Evolution

Experiments A and B (where resources were distributed to all cells) produced similar results. The "genetic" experiment (B) produced runs which took longer to become dominated by a single group. This would appear to result from the reduced communication of attribute information for the "genetic" experiment, since this only occurs when a cell on a group boundary "dies" by reaching an EL of zero. Also, copying of attribute information (reproduction) involves mutation, which was set at a high level here. With sparse rewards the "genetic" experiment (D) shows a marked difference in the optimality of the resource distribution in comparison with the cultural experiment (C).

5.5 Conclusions

The experiments presented in this chapter demonstrate that genetic and memetic forms of evolution lead to group formation (where groups are spatially connected regions

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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
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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
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Figure 5.7: Experiment A. The initial random starting values for each cell of the grid (as shown in figure 5.3, cycle 0). The values are randomly selected from a uniform distribution over each range. 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 (the C meme) has no direct behavioural significance.

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4339 4338 4337 4331 4333 4230 4335 4335 4336 4339 4339 4338 4334 4335 4337 4335 4339 4336 4336 4332
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Figure 5.8: Experiment A. The values for each cell of the grid by cycle 1500 (as shown in figure 5.3, 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.

of agents with identical memes). These can be identified visually in figures 5.3 to 5.6. The groups display in-group altruism and out-group selfishness. It has been demonstrated that in the simple scenarios presented, a genetic method of evolution produces societies which are less optimal (in the sense of keeping agents from reaching zero energy levels) than a memetic method. Where resources are rewarded to all cells (experiments A and B) the increase in optimality is small. In the "sparse reward" scenario (experiments C and D) the increase is much higher.

However, the main conclusion that is to be drawn from these experiments is this: *Simple satisfaction based cultural learning rules are sufficient to produce distinct, cultural groupings which can display a form of "memetic kin" altruism*, that is, altruistic behaviour induced at the agent level which is selfish at the cultural (or memetic) level. Groups in which all behave altruistically effectively share all the same memes (or genes in the genetic case). The altruism is therefore sustained due to the benefit given to kin. Kin are identified directly by the level of cultural (or genetic) similarity, which can be tested by agents before an altruistic donation.