Ray Alfano
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Assignment 1

Genetic Algorithms

Note: This code and the experimental data is entirely my own and no one elses. It was not informed by the work of any other student, nor was it contributed to in any way by other students. This submission reflects my own work, no one else's, without any reservation.

Instructions for running the simulator:

This code is written in Java. It is heavily based on the textbook's recommendations. The file to run is "../GenePoolSystem/src/gene/GenePoolSimulator". As with my other programs, the parameters are controlled by a configuration file config.properties, located in /GenePoolSystem/src/config.properties. Output is given as bitstrings representing genetic information over time and the relative fitness values associated with it. Average population fitness values are included.

Implementation notes:

The parameter values of generations, population, and mutation percentage affect values as the textbook indicates they should. The decay rate is a measure of how many organisms die per turn. The organisms that die are those that receive the highest random number value from the selection mechanism. The mutation mode is for the implementation of a static pivot point in the gene-representing bitstring,

I did not explicitly implement the roulette wheel model as my own experience in implementing it led me in a different direction and the assignment directions did not specifically require it. To control the population, I implemented a weighted-die mechanism. Each organism rolls at regular intervals (population * decay_rate) a weighted die each generation and subtracts its fitness from that number. The highest scoring organism in each interval dies. This effectively controls the population in a way that allows for diversity (and is biologically relevant). I also included an average fitness number for each generation to give a general idea of the population health over time. That is calculated simply by the relative fitness of all members divided by the population total.

The mutation/crossover modes implemented are static pivot, random pivot, and a random pivot with a chance to exchange genetic information. In my current implementation only one will be executed in a run-through of the program.

Experiments:

Experiment 1:
40 generations, population 40, 5% mutations, 0.1 decay rate, static pivot method

```
Starting Simulation...
Building Random Population... Done.

Initial Set:
[11100001, 11001111, 00011101]  Relative Fitness: 77
[01001100, 01111000, 01011101]  Relative Fitness: 95
[00101110, 11010000, 10010110]  Relative Fitness: 20
[10000001, 11111000, 00001000]  Relative Fitness: 1
[01001101, 11111000, 01101101]  Relative Fitness: 50
[11010011, 00111000, 11001101]  Relative Fitness: 88
[01011011, 10000101, 01000001]  Relative Fitness: 95
[00001110, 10010101, 01100111]  Relative Fitness: 118
[00110011, 10000101, 10001000]  Relative Fitness: 64
[01011001, 00101110, 11001001]  Relative Fitness: 48
[11001000, 10111010, 00100100]  Relative Fitness: 38
[11000010, 00000010, 10100010]  Relative Fitness: 26
[01110000, 10010111, 01010011]  Relative Fitness: 38
[00010000, 11101110, 00100110]  Relative Fitness: 92
[00000101, 11110100, 01100110]  Relative Fitness: 33
[11101100, 00101110, 01110000]  Relative Fitness: 10
[01010101, 10010010, 11100001]  Relative Fitness: 72
[11100001, 11000100, 00000100]  Relative Fitness: 41
[10100111, 11100001, 11110010]  Relative Fitness: 250
[00100111, 00110000, 00110000]  Relative Fitness: 249
[11110100, 10100010, 11111000]  Relative Fitness: 270
[01100001, 11101001, 11100011]  Relative Fitness: 173
[00001100, 11011000, 01000000]  Relative Fitness: 92
[00011110, 00001000, 00101111]  Relative Fitness: 299
[01110010, 10111001, 10010001]  Relative Fitness: 60
[01111001, 10100001, 11010000]  Relative Fitness: 106
[01000101, 01111111, 00000101]  Relative Fitness: 183
[01101011, 11011010, 10011110]  Relative Fitness: 99
[10111010, 11000010, 01101011]  Relative Fitness: 103
[10111010, 00011111, 01001101]  Relative Fitness: 90
[11111001, 00010001, 10100010]  Relative Fitness: 44
[00010110, 01110100, 11101011]  Relative Fitness: 11
[01001111, 10001010, 10111001]  Relative Fitness: 18
[10101011, 10111110, 11011000]  Relative Fitness: 193
[10001110, 11101000, 01110110]  Relative Fitness: 108
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[10011111, 10010110, 10100001] Relative Fitness: 86
[01000100, 11101111, 11001010] Relative Fitness: 125
[01011011, 01101111, 01000011] Relative Fitness: 115
[01000101, 10111000, 11100110] Relative Fitness: 99
[01101111, 00000101, 11000111] Relative Fitness: 69
Average Fitness: 96

Ending Set:
[01011000, 00101100, 00100111] Relative Fitness: 213
[01011000, 10011100, 11010000] Relative Fitness: 68
[01101010, 00111111, 00011010] Relative Fitness: 189
[10001001, 10100010, 01111011] Relative Fitness: 38
[01101100, 01111101, 01011100] Relative Fitness: 59
[01111110, 10101110, 11111001] Relative Fitness: 165
[01110101, 10011100, 10110110] Relative Fitness: 71
[01101111, 11101101, 01010001] Relative Fitness: 45
[01111100, 11001110, 01111000] Relative Fitness: 66
[01010011, 11111001, 11110000] Relative Fitness: 188
[01011010, 00110000, 11011010] Relative Fitness: 28
[01111100, 01110100, 01111101] Relative Fitness: 19
[10000101, 00000101, 00110111] Relative Fitness: 191
[10000010, 10110110, 10010101] Relative Fitness: 77
[01110000, 01001100, 01001100] Relative Fitness: 120
[01010111, 00010101, 01100101] Relative Fitness: 175
[01110010, 10001011, 10100101] Relative Fitness: 34
[01011000, 01100100, 01111100] Relative Fitness: 72
[01101000, 00011011, 01100101] Relative Fitness: 152
[01110010, 01110100, 11101111] Relative Fitness: 85
[01111100, 11111101, 11110101] Relative Fitness: 238
[01111000, 10010000, 00000011] Relative Fitness: 117
[01110111, 10011001, 11111001] Relative Fitness: 137
[01111110, 00001100, 01010001] Relative Fitness: 165
[01110011, 00110101, 01111111] Relative Fitness: 89
[01011111, 01001001, 10111111] Relative Fitness: 25
[01100011, 00110010, 10110101] Relative Fitness: 54
[01110000, 01011011, 11110000] Relative Fitness: 59
[01101011, 11010010, 10001111] Relative Fitness: 76
[01100100, 01111100, 01100000] Relative Fitness: 64
[01100110, 01011001, 00001110] Relative Fitness: 179
[01101001, 01100101, 01111011] Relative Fitness: 55
[01101100, 11100000, 10110110] Relative Fitness: 130
[01110000, 00100100, 10100001] Relative Fitness: 75
[01100110, 01010010, 11100101] Relative Fitness: 29
[01101100, 00110011, 11011001] Relative Fitness: 8

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[01101110, 11111100, 01011100]  Relative Fitness: 70
[01101001, 01000110, 01110100]  Relative Fitness: 93
[01110110, 01111010, 11011000]  Relative Fitness: 72
[01110011, 01100101, 00101111]  Relative Fitness: 121
Average Fitness: 97
End of Simulation.
```

Conclusions for experiment 1: The average fitness increases negligibly, and the number of highly fit and poor-fitness values diverge somewhat less from extremes but not vastly different from the original.

Experiment 2:
30 generations, population of 30, 10% mutations, 0.1 decay rate, static pivot method

```
Starting Simulation...
Building Random Population... Done.

Initial Set:
[01111110, 00111110, 11011001]  Relative Fitness: 21
[00101010, 11010110, 01000000]  Relative Fitness: 64
[11100011, 10101110, 10011100]  Relative Fitness: 173
[00010100, 11101011, 11001110]  Relative Fitness: 77
[11011110, 00101010, 10101010]  Relative Fitness: 50
[00110111, 00011011, 11000100]  Relative Fitness: 106
[10101000, 11011010, 01000001]  Relative Fitness: 67
[11101101, 10110110, 10110000]  Relative Fitness: 211
[00001110, 01100001, 10010001]  Relative Fitness: 128
[00001111, 11001001, 00101100]  Relative Fitness: 124
[01111111, 01001000, 10111001]  Relative Fitness: 0
[00000111, 00100110, 01110111]  Relative Fitness: 220
[10010101, 00001110, 10001111]  Relative Fitness: 78
[10000100, 00110010, 11110111]  Relative Fitness: 45
[10000111, 01000001, 11111000]  Relative Fitness: 64
[00100100, 11100111, 10110101]  Relative Fitness: 64
[11110100, 00111111, 01100100]  Relative Fitness: 23
[00000110, 10100111, 01101011]  Relative Fitness: 104
[00110000, 11111100, 01011000]  Relative Fitness: 4
[10100100, 00110101, 01110011]  Relative Fitness: 52
[01010101, 11101110, 10110100]  Relative Fitness: 119
[11101000, 10100111, 10111011]  Relative Fitness: 202
[10110001, 01000000, 11000110]  Relative Fitness: 55
[00101000, 11000110, 00110011]  Relative Fitness: 95
[00100010, 00010010, 10100011]  Relative Fitness: 169
[10001111, 00101011, 11001100]  Relative Fitness: 6
[11010100, 10100000, 11101111]  Relative Fitness: 227
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[11100000, 11111001, 00101010]   Relative Fitness: 131
[01101010, 11101000, 00100010]   Relative Fitness: 12
[01001111, 10000110, 01000011]   Relative Fitness: 104
Average Fitness: 93

Ending Set:
[11101101, 10110110, 10110000]   Relative Fitness: 211
[11001100, 00111010, 01101100]   Relative Fitness: 14
[01111010, 10000000, 01010000]   Relative Fitness: 54
[00100011, 11100000, 00110100]   Relative Fitness: 73
[01100111, 11000110, 11110101]   Relative Fitness: 162
[00010101, 01110000, 00101111]   Relative Fitness: 204
[10000110, 01111101, 01010101]   Relative Fitness: 40
[01011110, 11101010, 01100001]   Relative Fitness: 41
[00100010, 00000000, 01100110]   Relative Fitness: 248
[10010111, 10111001, 01000101]   Relative Fitness: 21
[10001101, 11111001, 10011000]   Relative Fitness: 158
[01101010, 01011101, 10011101]   Relative Fitness: 28
[01011011, 01111000, 10001011]   Relative Fitness: 34
[01101110, 11001101, 10100001]   Relative Fitness: 92
[01011110, 00000010, 11000100]   Relative Fitness: 92
[01100011, 01010001, 10110001]   Relative Fitness: 27
[01101010, 00001101, 00011011]   Relative Fitness: 238
[01000010, 00011110, 11101000]   Relative Fitness: 56
[01001001, 01111010, 11010110]   Relative Fitness: 25
[00111111, 10111110, 10100101]   Relative Fitness: 34
[01110011, 11110001, 00101000]   Relative Fitness: 12
[01010100, 00110010, 10011100]   Relative Fitness: 94
[01110001, 10111001, 00100110]   Relative Fitness: 48
[01100111, 00000110, 01011111]   Relative Fitness: 180
[01011001, 00011010, 10110000]   Relative Fitness: 93
[01010001, 10110100, 01110000]   Relative Fitness: 11
[01000000, 11101110, 11000111]   Relative Fitness: 117
[10010010, 11011001, 01101111]   Relative Fitness: 90
[01010010, 10111000, 01001101]   Relative Fitness: 41
[01101111, 00100111, 01100011]   Relative Fitness: 135
Average Fitness: 89
End of Simulation.
```

Conclusions on experiment 2: A somewhat wider variation in the “winners and losers” can be seen in the results set. The relative fitness diverges over generations in this model, but the average fitness declines only slightly.

Experiment 3:

75 generations, 50 population, 17% mutation rate, 0.1 decay rate, dynamic pivot

```
Starting Simulation...
Building Random Population... Done.

Initial Set:
[10010111, 00001101, 01100100]   Relative Fitness: 120
[00001111, 00000100, 00010001]   Relative Fitness: 348
[00010001, 10111111, 00101110]   Relative Fitness: 130
[01110001, 01100110, 01011100]   Relative Fitness: 77
[00110100, 00110110, 00011101]   Relative Fitness: 249
[01100100, 10111111, 00010011]   Relative Fitness: 74
[00100000, 11010100, 10100011]   Relative Fitness: 23
[01000100, 10100011, 11101101]   Relative Fitness: 84
[10101101, 10001000, 01001111]   Relative Fitness: 4
[10001010, 10110010, 11000010]   Relative Fitness: 126
[11011101, 10101101, 10001001]   Relative Fitness: 147
[00101111, 00101111, 01000110]   Relative Fitness: 220
[11000010, 10000111, 01011110]   Relative Fitness: 39
[00100010, 01101001, 01101001]   Relative Fitness: 140
[01001110, 01110011, 11100111]   Relative Fitness: 40
[11111100, 10011100, 10101110]   Relative Fitness: 198
[11110010, 10110011, 10110011]   Relative Fitness: 216
[10001111, 00010111, 11001000]   Relative Fitness: 18
[10111110, 11110110, 01111100]   Relative Fitness: 176
[01001000, 01100101, 00011000]   Relative Fitness: 187
[01011110, 10101110, 01001011]   Relative Fitness: 41
[11111101, 10001010, 11111000]   Relative Fitness: 255
[00111101, 11000010, 01110000]   Relative Fitness: 17
[00001111, 11000110, 01111001]   Relative Fitness: 50
[10110000, 01000100, 00110010]   Relative Fitness: 90
[00000101, 00011110, 01001111]   Relative Fitness: 270
[10010110, 01010011, 01111000]   Relative Fitness: 31
[00110101, 01111010, 01001101]   Relative Fitness: 132
[10101110, 11010010, 00001000]   Relative Fitness: 8
[10010110, 01111000, 11000011]   Relative Fitness: 81
[01000011, 01101101, 11001100]   Relative Fitness: 4
[01000101, 00000111, 11010110]   Relative Fitness: 94
[00001110, 01010100, 11101001]   Relative Fitness: 53
[11111110, 10101010, 11101111]   Relative Fitness: 279
[11011011, 10000110, 01000110]   Relative Fitness: 39
[00100010, 10011100, 01101100]   Relative Fitness: 86
[11001100, 11111001, 01000110]   Relative Fitness: 139
[00011100, 10110000, 00011010]   Relative Fitness: 154
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[11011111, 01000100, 01011001] Relative Fitness: 4
[01011010, 11000001, 10000001] Relative Fitness: 28
[10010010, 00111011, 10101111] Relative Fitness: 4
[01100001, 10100101, 10110000] Relative Fitness: 54
[10101110, 01100001, 00100000] Relative Fitness: 81
[11010101, 00111001, 01000010] Relative Fitness: 48
[10101100, 10110111, 00110100] Relative Fitness: 23
[10010001, 00100101, 01011011] Relative Fitness: 111
[11010110, 11011000, 01110000] Relative Fitness: 158
[00011110, 11110011, 00110101] Relative Fitness: 58
[00110000, 10010011, 01011110] Relative Fitness: 95
[00011100, 01100101, 10111101] Relative Fitness: 66
Average Fitness: 103

Ending Set:
[01011010, 10000001, 00001000] Relative Fitness: 157
[00000000, 00000000, 00000000] Relative Fitness: 384
[00100000, 10000000, 00011010] Relative Fitness: 198
[01001111, 10001101, 10011001] Relative Fitness: 11
[01010100, 01101111, 10111000] Relative Fitness: 5
[00100110, 00101111, 01001100] Relative Fitness: 223
[00100101, 10010011, 10101011] Relative Fitness: 29
[00010010, 11001001, 11010110] Relative Fitness: 49
[00110111, 01001100, 11000111] Relative Fitness: 54
[00111000, 00011011, 11111100] Relative Fitness: 49
[00110110, 01010011, 00101000] Relative Fitness: 207
[00000000, 00000000, 00000000] Relative Fitness: 384
[00111101, 11000000, 10010100] Relative Fitness: 17
[00100011, 00010111, 00110010] Relative Fitness: 276
[00000000, 10000000, 00001000] Relative Fitness: 248
[00000000, 00000100, 00000000] Relative Fitness: 380
[01000110, 01100010, 00101111] Relative Fitness: 169
[01000100, 01101111, 10010110] Relative Fitness: 55
[00100111, 11001000, 11001101] Relative Fitness: 60
[00000000, 00000000, 00000000] Relative Fitness: 384
[00111110, 01100010, 00011110] Relative Fitness: 194
[01000000, 00110110, 10110010] Relative Fitness: 88
[00111000, 10001111, 01110010] Relative Fitness: 71
[00110010, 10010110, 11100110] Relative Fitness: 46
[00000100, 00010000, 00000000] Relative Fitness: 364
[00100111, 01111000, 11010001] Relative Fitness: 16
[00000000, 10000000, 00011000] Relative Fitness: 232
[01000101, 01101000, 11100011] Relative Fitness: 16
[00100101, 01001101, 10001111] Relative Fitness: 127

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[00000100, 00010000, 00000000]   Relative Fitness: 364
[01000000, 00001000, 00010010]   Relative Fitness: 294
[00010000, 10001001, 10000010]   Relative Fitness: 101
[00000100, 00001101, 00010000]   Relative Fitness: 351
[00011110, 00110010, 01010011]   Relative Fitness: 221
[00111000, 01110010, 00001100]   Relative Fitness: 202
[00111100, 01011001, 10101110]   Relative Fitness: 61
[00011100, 01000111, 10111001]   Relative Fitness: 100
[00101100, 00011001, 01011101]   Relative Fitness: 222
[00100101, 10011101, 11110001]   Relative Fitness: 51
[00110000, 10010101, 10111011]   Relative Fitness: 0
[00100100, 10111010, 11111010]   Relative Fitness: 88
[00110101, 11110100, 00110100]   Relative Fitness: 35
[00111101, 00000001, 10110010]   Relative Fitness: 144
[00011101, 00000010, 00011010]   Relative Fitness: 327
[00101011, 01101001, 10100001]   Relative Fitness: 75
[00100000, 00000100, 10000110]   Relative Fitness: 214
[00000000, 00000000, 00001000]   Relative Fitness: 376
[00000101, 00000000, 10100010]   Relative Fitness: 217
[00011010, 01010010, 11011110]   Relative Fitness: 54
[00010010, 10011101, 10001001]   Relative Fitness: 72
Average Fitness: 161
End of Simulation.
```

Conclusions for experiment 3: Interestingly, the relative fitness increased by quite a bit while maintaining some similarities of individual organisms from the first set.

Experiment 4:
75 generations, 50 population, 4% mutation rate, 0.2 decay rate, dynamic pivot

```
Starting Simulation...
Building Random Population... Done.

Initial Set:
[11011000, 01010011, 00111100]   Relative Fitness: 25
[10010100, 11010001, 10011001]   Relative Fitness: 126
[10100000, 11110101, 11110100]   Relative Fitness: 265
[10111010, 01101011, 11111110]   Relative Fitness: 163
[01101010, 01011110, 10100100]   Relative Fitness: 20
[11011110, 00010100, 01111010]   Relative Fitness: 20
[10010100, 11110100, 10101100]   Relative Fitness: 180
[01101111, 00000010, 01110000]   Relative Fitness: 159
[01111111, 01110001, 10011010]   Relative Fitness: 10
[00001111, 11111110, 10010010]   Relative Fitness: 31
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```
[10111110, 10011100, 10100111]   Relative Fitness: 129
[11011101, 10011011, 01001110]   Relative Fitness: 70
[11001101, 00100010, 11110110]   Relative Fitness: 101
[11111101, 10111100, 00111100]   Relative Fitness: 117
[01001100, 00010110, 11001111]   Relative Fitness: 79
[01100100, 10101000, 01111010]   Relative Fitness: 6
[01011000, 11111011, 11111101]   Relative Fitness: 208
[00011011, 11011111, 11101111]   Relative Fitness: 105
[00111011, 11011101, 01011000]   Relative Fitness: 16
[01110110, 00101001, 10111101]   Relative Fitness: 36
[10010010, 00000001, 00101001]   Relative Fitness: 196
[10011000, 10001001, 10001001]   Relative Fitness: 42
[00001011, 01001110, 10100011]   Relative Fitness: 132
[01001110, 10111110, 01110101]   Relative Fitness: 1
[11011010, 10011001, 01100010]   Relative Fitness: 85
[01011000, 01001110, 10111111]   Relative Fitness: 27
[01111100, 11101100, 01001000]   Relative Fitness: 48
[10100100, 11101100, 11101101]   Relative Fitness: 253
[10010110, 11101000, 00010101]   Relative Fitness: 19
[00001010, 01001101, 01010100]   Relative Fitness: 213
[01010010, 10100010, 00100110]   Relative Fitness: 102
[01110010, 01011101, 10110111]   Relative Fitness: 6
[00110000, 01010101, 11001011]   Relative Fitness: 48
[11001100, 00111111, 01110010]   Relative Fitness: 3
[00111111, 11100110, 10100001]   Relative Fitness: 70
[11011011, 00000001, 10110110]   Relative Fitness: 18
[01101110, 01111001, 01000110]   Relative Fitness: 83
[11111000, 10110010, 01111001]   Relative Fitness: 163
[11100110, 01011011, 10101011]   Relative Fitness: 108
[01010000, 10011010, 00001010]   Relative Fitness: 140
[01100001, 10000100, 10110000]   Relative Fitness: 21
[11101111, 00011100, 11111000]   Relative Fitness: 131
[01000011, 01110101, 11100111]   Relative Fitness: 31
[11100001, 10101010, 01000101]   Relative Fitness: 80
[01010001, 11010100, 01010011]   Relative Fitness: 8
[00111000, 11110010, 10011000]   Relative Fitness: 66
[00000001, 11000000, 11101000]   Relative Fitness: 41
[10011111, 11000110, 01000101]   Relative Fitness: 42
[10110010, 01110110, 00011011]   Relative Fitness: 61
[00001001, 00011110, 10111101]   Relative Fitness: 156
Average Fitness: 85

Ending Set:
[01101000, 01010011, 00111000]   Relative Fitness: 141
```

[01101101, 11111000, 10010110] Relative Fitness: 123
[01101011, 00011001, 00001111] Relative Fitness: 237
[01100101, 11111110, 00000011] Relative Fitness: 26
[01100001, 11110000, 10000010] Relative Fitness: 83
[01100111, 00010100, 10010111] Relative Fitness: 110
[01100110, 00111100, 10011100] Relative Fitness: 66
[01101001, 01101001, 01000000] Relative Fitness: 110
[01101000, 00111101, 01010111] Relative Fitness: 132
[01101010, 10110011, 01101010] Relative Fitness: 7
[01101011, 00100100, 11110000] Relative Fitness: 1
[01100111, 01000111, 11010110] Relative Fitness: 4
[01101000, 00101110, 01100000] Relative Fitness: 138
[01100111, 11000000, 11011011] Relative Fitness: 130
[01101001, 01010000, 11000110] Relative Fitness: 1
[01101001, 11001001, 00001101] Relative Fitness: 65
[01101001, 00110011, 11001101] Relative Fitness: 23
[01101000, 11000101, 01010011] Relative Fitness: 0
[01101010, 01111110, 01101101] Relative Fitness: 43
[01011001, 11101000, 11110101] Relative Fitness: 182
[01100101, 11011010, 10010111] Relative Fitness: 86
[01100101, 01001011, 01011100] Relative Fitness: 116
[01101001, 11110111, 00001011] Relative Fitness: 21
[01101001, 11110011, 11010111] Relative Fitness: 179
[01101000, 01101111, 00100001] Relative Fitness: 136
[01101001, 10010011, 11010010] Relative Fitness: 78
[01100110, 00000001, 00110011] Relative Fitness: 230
[01100110, 11000101, 10110010] Relative Fitness: 93
[01100111, 01101110, 01000011] Relative Fitness: 104
[01100010, 01111000, 11000110] Relative Fitness: 32
[01100110, 11101110, 01101100] Relative Fitness: 64
[01100111, 10100000, 10100101] Relative Fitness: 44
[01100111, 10000100, 01011001] Relative Fitness: 60
[01100110, 11001111, 01001010] Relative Fitness: 1
[01101001, 00011100, 11000100] Relative Fitness: 55
[01100111, 11000010, 10010111] Relative Fitness: 64
[01100010, 01101110, 01000001] Relative Fitness: 111
[01101000, 11100111, 00100100] Relative Fitness: 13
[01100100, 10011110, 11000110] Relative Fitness: 72
[01101001, 01111110, 01000011] Relative Fitness: 86
[01100011, 11100010, 00010001] Relative Fitness: 42
[01100100, 11110101, 00010001] Relative Fitness: 22
[01100101, 10110111, 00001000] Relative Fitness: 92
[01100111, 01101111, 10010111] Relative Fitness: 19
[01101001, 00110110, 01100011] Relative Fitness: 126

```
[01100010, 11101001, 01001010]  Relative Fitness: 21
[01100110, 11011101, 11000101]  Relative Fitness: 136
[01101000, 01011010, 01001111]  Relative Fitness: 111
[01100111, 01001011, 01110110]  Relative Fitness: 88
[01100101, 10011110, 01000001]  Relative Fitness: 60
Average Fitness: 79
End of Simulation.
```

Conclusions for experiment 4: A higher death rate and less mutations caused a slow general decline in the population. Most members of the gene pool are doing worse or at least not well. The average fitness only declines slightly.

Experiment 5:
300 generations, 40 population, 10% mutation rate, 0.1 decay rate, dynamic pivot with chance to swap.

```
Starting Simulation...
Building Random Population... Done.

Initial Set:
[10000110, 10001101, 10011110]  Relative Fitness: 49
[00010001, 11011010, 00011110]  Relative Fitness: 119
[10011010, 00001010, 10101100]  Relative Fitness: 48
[11000000, 01100000, 00011111]  Relative Fitness: 65
[11001000, 01011110, 00100010]  Relative Fitness: 56
[00011101, 11000111, 11111101]  Relative Fitness: 97
[10101010, 01010010, 11010110]  Relative Fitness: 82
[01010101, 10000111, 00001101]  Relative Fitness: 151
[11001100, 00010111, 01001101]  Relative Fitness: 80
[10010101, 11100011, 10000000]  Relative Fitness: 120
[00011011, 01110111, 10011010]  Relative Fitness: 84
[11100011, 01010001, 10010011]  Relative Fitness: 71
[10100011, 10010111, 10011101]  Relative Fitness: 87
[11001010, 01101010, 00010101]  Relative Fitness: 55
[11101100, 10100000, 00000000]  Relative Fitness: 12
[01001010, 01110111, 00010011]  Relative Fitness: 172
[01011010, 01100111, 00011000]  Relative Fitness: 167
[11101110, 11101100, 00010001]  Relative Fitness: 107
[10101000, 01101011, 10000100]  Relative Fitness: 23
[11011111, 01001100, 10011101]  Relative Fitness: 72
[00101110, 11001110, 00111010]  Relative Fitness: 74
[01010001, 01101110, 10111101]  Relative Fitness: 4
[10111101, 10011010, 10110100]  Relative Fitness: 139
[11011111, 10111110, 11101101]  Relative Fitness: 266
```

[10000110, 11110000, 01000100] Relative Fitness: 58
[01110010, 11010010, 01001011] Relative Fitness: 15
[11110011, 00001010, 11010101] Relative Fitness: 82
[00001111, 11100001, 01011001] Relative Fitness: 55
[10110100, 01001100, 00000111] Relative Fitness: 121
[00111100, 00001101, 11110110] Relative Fitness: 65
[01001110, 00001010, 00001011] Relative Fitness: 285
[01000010, 11111010, 00100111] Relative Fitness: 29
[01110100, 01011111, 00001101] Relative Fitness: 160
[01010111, 10110110, 10011010] Relative Fitness: 39
[10110011, 10101011, 01001111] Relative Fitness: 45
[10010011, 01101101, 01011111] Relative Fitness: 33
[00111000, 11110101, 00001010] Relative Fitness: 73
[01110100, 01001000, 11001100] Relative Fitness: 8
[11111011, 00101110, 00000011] Relative Fitness: 84
[10111100, 10011001, 01001001] Relative Fitness: 30
Average Fitness: 84

Ending Set:
[01000101, 11011000, 01110011] Relative Fitness: 16
[01001000, 00011101, 00100000] Relative Fitness: 251
[01000110, 01010110, 10000010] Relative Fitness: 98
[00100100, 00110011, 01100110] Relative Fitness: 195
[01001000, 11111111, 01011100] Relative Fitness: 35
[00110100, 11111100, 01001000] Relative Fitness: 8
[01000111, 01001111, 10111101] Relative Fitness: 45
[01001000, 10110100, 01100011] Relative Fitness: 33
[00100100, 01001111, 00011010] Relative Fitness: 243
[01000111, 01111100, 10011010] Relative Fitness: 35
[00110101, 00111000, 11101110] Relative Fitness: 37
[00011011, 10000110, 01001001] Relative Fitness: 150
[00001001, 10000110, 01000001] Relative Fitness: 176
[01000111, 01001100, 00001011] Relative Fitness: 226
[00100010, 01000000, 11001011] Relative Fitness: 83
[00100010, 11000110, 10010101] Relative Fitness: 3
[01000111, 00111001, 10010000] Relative Fitness: 112
[00010110, 11101010, 10101110] Relative Fitness: 46
[00000100, 11101010, 00000000] Relative Fitness: 146
[01000110, 11010001, 01011001] Relative Fitness: 16
[01000110, 11101011, 10110000] Relative Fitness: 97
[00100011, 10001010, 11011000] Relative Fitness: 5
[00111001, 01110011, 00011110] Relative Fitness: 182
[00010000, 10000100, 01001000] Relative Fitness: 164
[01000000, 01110111, 11011100] Relative Fitness: 19

```
[00000011, 00000000, 00001000]   Relative Fitness: 373
[00110101, 00000000, 00010011]   Relative Fitness: 312
[00110100, 10110001, 10100110]   Relative Fitness: 11
[00110100, 01110110, 11011000]   Relative Fitness: 2
[00001000, 00010010, 00000010]   Relative Fitness: 356
[00101100, 01010100, 11000111]   Relative Fitness: 57
[00110101, 00010001, 00000000]   Relative Fitness: 314
[00010000, 00000000, 01001000]   Relative Fitness: 296
[00111110, 01100111, 01010101]   Relative Fitness: 134
[00110010, 01011001, 11000000]   Relative Fitness: 53
[00001001, 10000110, 01000001]   Relative Fitness: 176
[00111001, 10110001, 11001111]   Relative Fitness: 57
[00011111, 01000011, 00101010]   Relative Fitness: 244
[00011111, 01011111, 10011000]   Relative Fitness: 106
[01000000, 00000100, 00101001]   Relative Fitness: 275
Average Fitness: 129
End of Simulation.
```

Conclusions on experiment 5: Some members became extremely fit and the average fitness increased by a large degree. Next I will contrast that with a static pivot for the same initial values.

Experiment 6:
Generations 300, population 40, 10% mutation rate, 0.1 decay rate, static pivot

```
Starting Simulation...
Building Random Population... Done.

Initial Set:
[01110100, 00001001, 00000101]   Relative Fitness: 254
[11010010, 11001101, 00100011]   Relative Fitness: 66
[10010110, 11111010, 11111011]   Relative Fitness: 267
[01001100, 01111000, 00101000]   Relative Fitness: 148
[10110100, 01010110, 11101001]   Relative Fitness: 115
[01010010, 01000101, 11100010]   Relative Fitness: 7
[01000010, 00111000, 00110101]   Relative Fitness: 209
[00010110, 01010011, 10110100]   Relative Fitness: 99
[10001100, 00101101, 11001010]   Relative Fitness: 3
[01101111, 10011010, 11001111]   Relative Fitness: 88
[01111001, 10001010, 01100001]   Relative Fitness: 28
[11000111, 00011000, 10001101]   Relative Fitness: 20
[00011100, 11010111, 01001001]   Relative Fitness: 68
[00011011, 00110111, 10011111]   Relative Fitness: 143
[10010000, 11100100, 01011100]   Relative Fitness: 80
```

```
[10001010, 00001010, 10001100]   Relative Fitness: 96
[00011000, 00110010, 00000110]   Relative Fitness: 304
[00000010, 11010011, 11000111]   Relative Fitness: 28
[00101110, 01010000, 11000011]   Relative Fitness: 63
[10010100, 10010100, 10010100]   Relative Fitness: 60
[10111000, 01011010, 00001101]   Relative Fitness: 97
[10000110, 00011100, 00010000]   Relative Fitness: 206
[00010101, 11111001, 01100101]   Relative Fitness: 13
[01100001, 00001011, 01010100]   Relative Fitness: 192
[11010101, 10110011, 10011111]   Relative Fitness: 167
[00011111, 11000101, 10111100]   Relative Fitness: 32
[01100001, 00111111, 01100011]   Relative Fitness: 125
[11101010, 00110111, 00110001]   Relative Fitness: 46
[11001011, 11010000, 01000100]   Relative Fitness: 95
[11100110, 10011011, 11110011]   Relative Fitness: 244
[00010001, 11111101, 01111100]   Relative Fitness: 10
[10110011, 00100111, 00000110]   Relative Fitness: 160
[11100111, 11011011, 01111000]   Relative Fitness: 186
[01100011, 10011011, 11010110]   Relative Fitness: 84
[01010001, 10110010, 10000010]   Relative Fitness: 5
[00101011, 01010000, 00110100]   Relative Fitness: 209
[10100011, 10000110, 10000101]   Relative Fitness: 46
[01111110, 11100010, 11000100]   Relative Fitness: 164
[10010100, 00100111, 10110111]   Relative Fitness: 14
[01010110, 01100100, 11001010]   Relative Fitness: 4
Average Fitness: 106

Ending Set:
[10001100, 00011111, 11110100]   Relative Fitness: 31
[10001100, 01010011, 00101111]   Relative Fitness: 114
[10001100, 01000011, 01000000]   Relative Fitness: 113
[10001100, 00111010, 10100010]   Relative Fitness: 24
[10001100, 01101100, 01111100]   Relative Fitness: 12
[10001100, 00001100, 11100101]   Relative Fitness: 3
[10001100, 00000000, 11101101]   Relative Fitness: 7
[10001100, 00110100, 11100000]   Relative Fitness: 32
[10001100, 00111100, 01101000]   Relative Fitness: 80
[10001100, 00011101, 00110011]   Relative Fitness: 164
[10001100, 00100010, 01101011]   Relative Fitness: 103
[10001100, 00111101, 01111010]   Relative Fitness: 61
[10001100, 00100001, 11010001]   Relative Fitness: 2
[10001100, 00110000, 11001101]   Relative Fitness: 9
[10001100, 00100111, 00000000]   Relative Fitness: 205
[10001100, 00011101, 01001011]   Relative Fitness: 140
```

[10001100, 00111100, 00010000] Relative Fitness: 168
[10001100, 01000010, 00111001] Relative Fitness: 121
[10001100, 00111101, 00011001] Relative Fitness: 158
[10001100, 00011110, 11001001] Relative Fitness: 13
[10001100, 01000110, 11111010] Relative Fitness: 76
[10001100, 00010010, 00101111] Relative Fitness: 179
[10001100, 00010010, 10000110] Relative Fitness: 92
[10001100, 00001000, 00000011] Relative Fitness: 233
[10001100, 00000001, 00101111] Relative Fitness: 196
[10001100, 00111111, 10010011] Relative Fitness: 34
[10001100, 00011111, 10001110] Relative Fitness: 71
[10001100, 00110010, 00111101] Relative Fitness: 133
[10001100, 00011011, 11101000] Relative Fitness: 15
[10001100, 00100011, 01100001] Relative Fitness: 112
[10001100, 00000111, 00001010] Relative Fitness: 227
[10001100, 00111000, 11110000] Relative Fitness: 52
[10001100, 01000000, 01011101] Relative Fitness: 87
[10001100, 01010111, 01011011] Relative Fitness: 66
[10001100, 00011011, 11101100] Relative Fitness: 19
[10001100, 01000001, 01101011] Relative Fitness: 72
[10001100, 01001000, 01010101] Relative Fitness: 87
[10001100, 00111000, 11111100] Relative Fitness: 64
[10001100, 00100101, 10010110] Relative Fitness: 57
[10001100, 00111010, 10101100] Relative Fitness: 14
Average Fitness: 86
End of Simulation.

Conclusion for Experiment 6: The results of experiment 6 are not as beneficial to the population as in the dynamic pivot with chance to swap model. This is borne out over multiple run-throughs.