Life from Ash: Software Description

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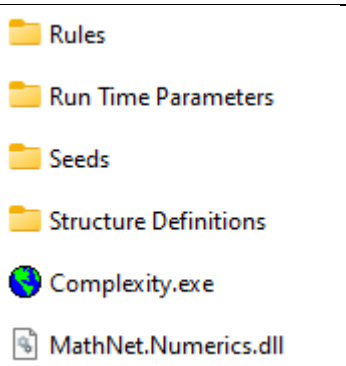
How to Install the Software

The software was developed with the current version of Visual Studio 2022 and operates on a Windows 10 or 11 computer. The "Life from Ash Executable.zip" file, when downloaded from GitHub, can be decompressed into a directory on the computer's hard drive and will contain the following structure:



The executable file is "Complexity.exe" and "MathNetNumerics.dll" provides some of the analytical functions used by the software. No database is used for the software; all data is contained in simple text files.

The support folders contain the following information used by the software:

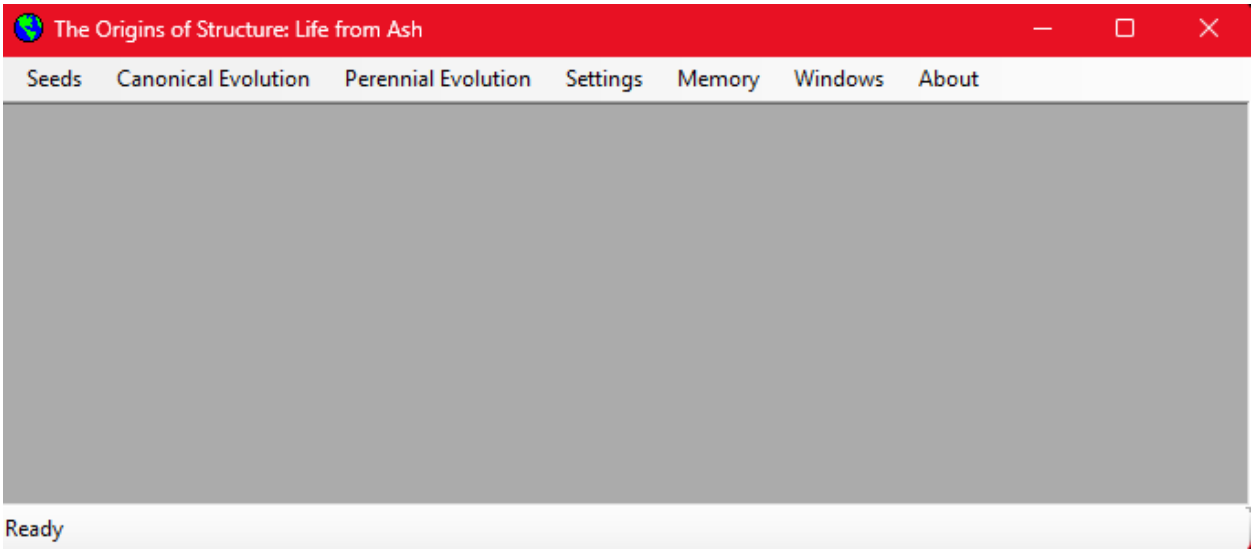
- Rules: contains the current three CA rule sets used by the software. Primary among them is the canonical CA rule, B3/S23.
- Run Time Parameters: two files that control key functions for CA evolution and analysis.
- Seeds: contains all the text files used to create the CA structures for the figures and tables described in the Life from Ash paper.
- Structure Definitions: contains text files that help identify CA structures during evolution.

This software is memory intensive due to the nature of CA evolution and the metrics collected during that evolution for analytical purposes. The computer used to develop this software runs Windows 11 with a 12th generation Intel i9 core at 2.4 GHz with 64 GB of installed RAM. Running "Complexity" with as few other programs operating in the background is recommended.

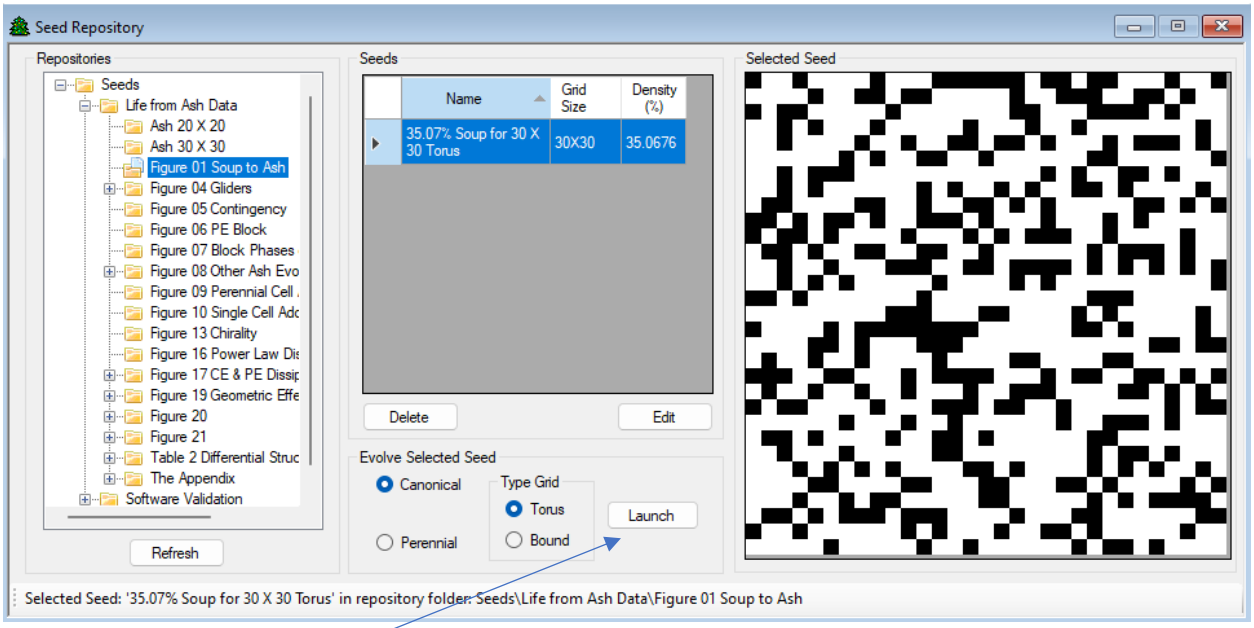
The purpose of the pages that follow is to provide a brief walk-thru of how the data presented in the Life from Ash paper was created. As with all software, learning by doing is often the best self-teaching method.

Basic Operation

The software model is a classic multiple document user interface (MDI) designed for easily containing the various work and analysis windows.



To reproduce, for example, the canonical evolution (CE) shown in Figure 1 of the paper, open the Seed Repository from the Seeds\Repository menu and select “Figure 01 Soup to Ash” in the tree view.



Select the “Launch” button and the Canonical Evolution window shown in the next section will be instantiated.

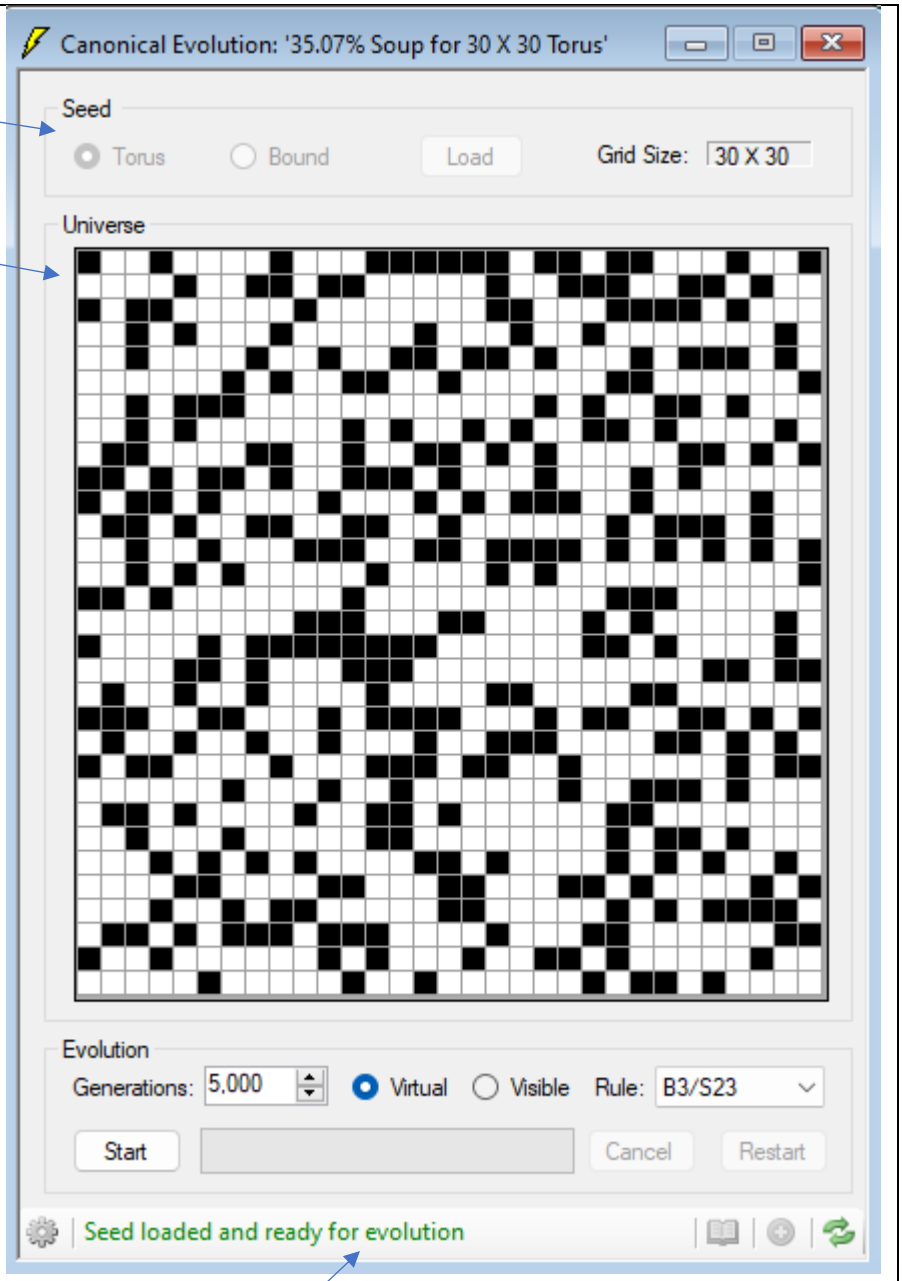
Canonical Evolution

This area shows the details about the seed that was selected.

The random soup is shown here, prior to the start of evolution.

Controls for the evolution are below the “Universe” and allow the following functions:

- Generations: the maximum allowed is 100,000.
- Virtual: this is the default view where evolution isn’t shown on the screen until completed.
- Visible: allows evolution to be observed, but at a slower rate than the virtual mode.
- Rule: the default is shown.
- Start: begins evolution.
- Cancel: cancels evolution after it is started.
- Restart: rerun the evolution after it has been completed.

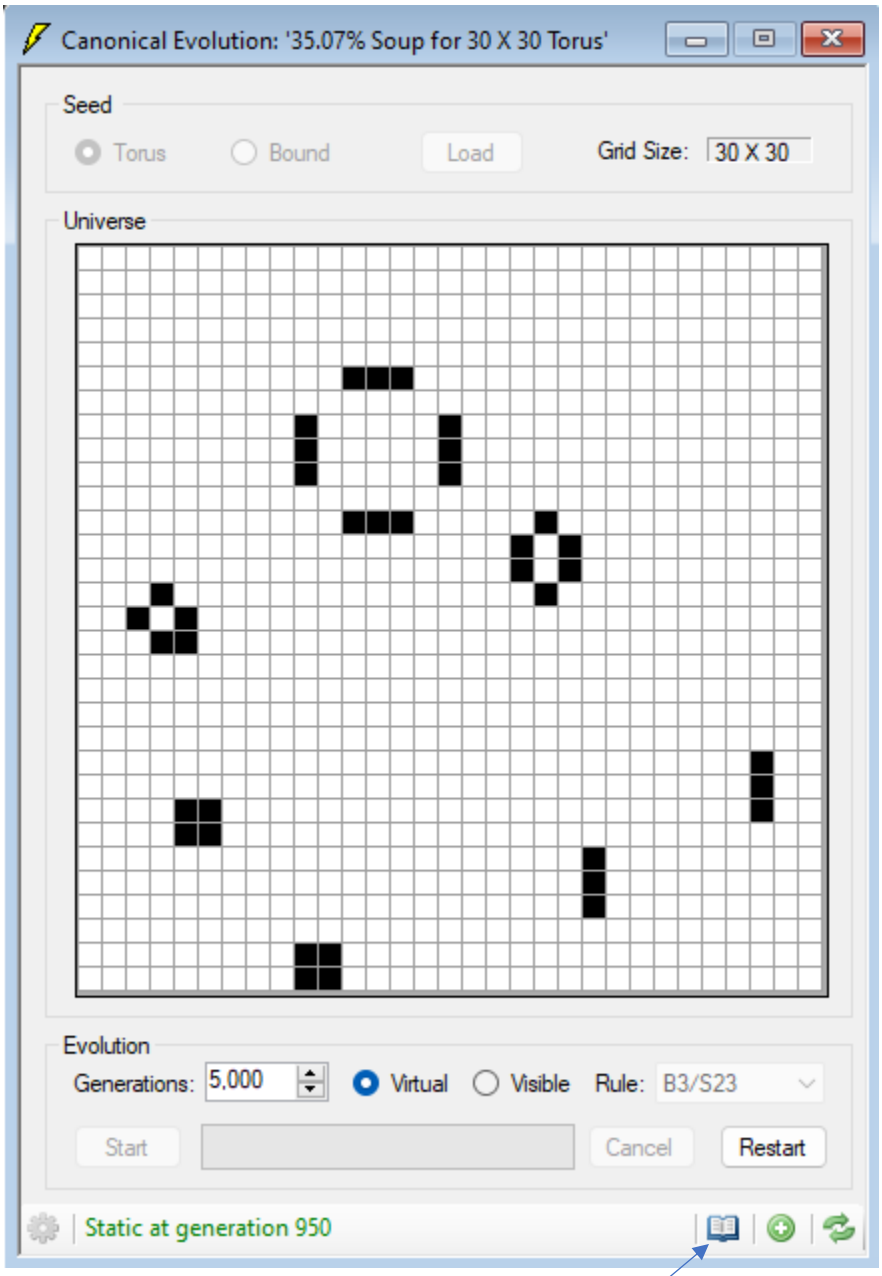


Buttons on the status bar at the bottom of the window will be discussed on the pages that follow.

This soup could also be loaded using the “Load” button at the top of the window if it is launched from the main menu selection “Canonical Evolution\Single Canonical Seed.

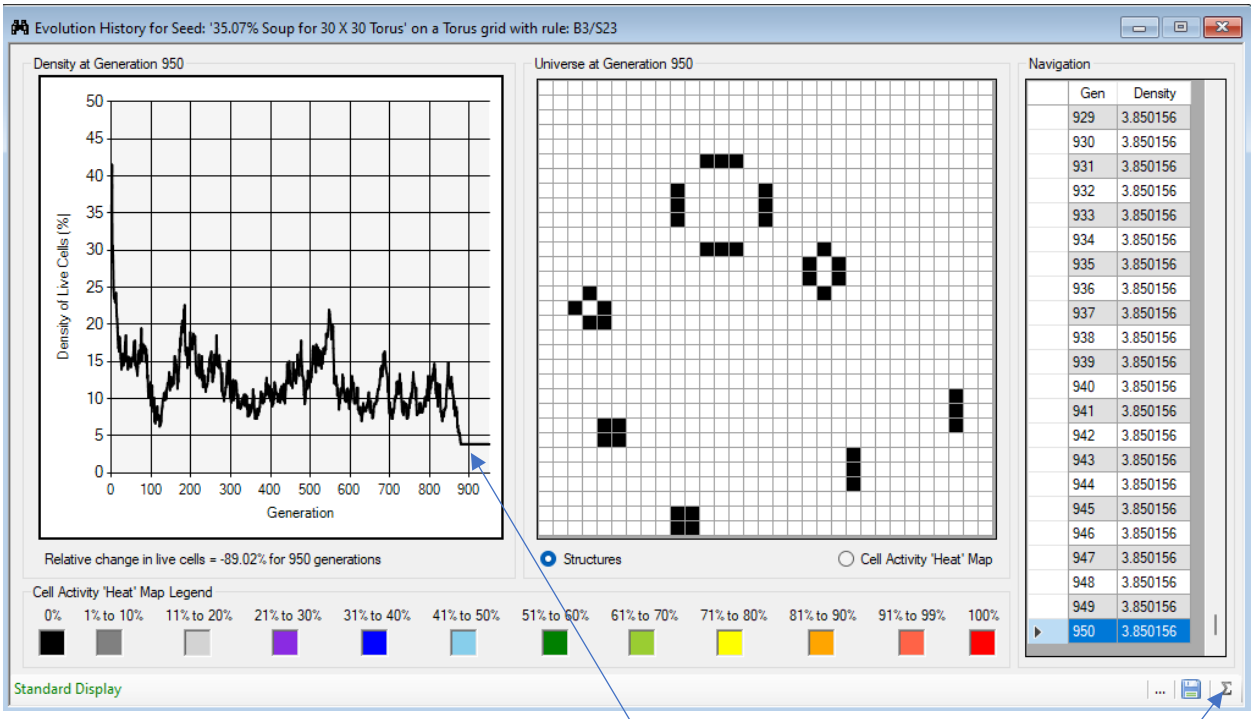
Select start…

…and after several seconds the evolution will complete, and the window will look like this:



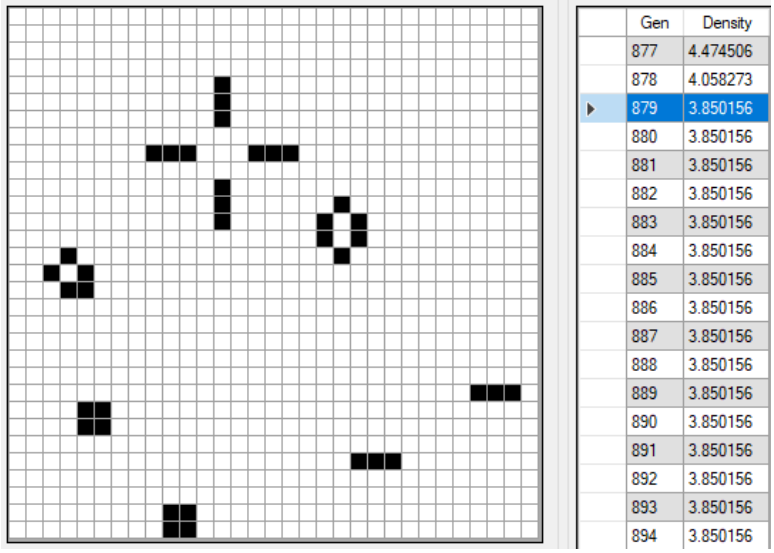
The history of this evolution can be seen by selecting this button and the Evolution History window will appear, discussed in the next section.

Evolution History



Beneath many of the grids in the software, an "Export" button allows the exporting of grid data to the clipboard for analysis in Excel. The button to the left of the "Export" button allows the currently selected generation's pattern to be saved to disk as a new seed.

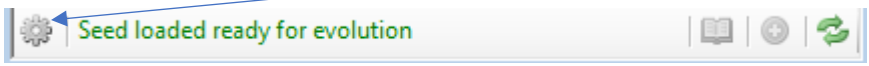
Density changes during evolution are shown on the left-hand side of the window and to the right is the end state of the evolution. The "Navigation" section on the far right allows inspection of evolution at any cycle. For example, this soup actually became static at 879 generations and by selecting this cycle in the navigation grid will show a slightly different end state as shown below.



Gen	Density
877	4.474506
878	4.058273
879	3.850156
880	3.850156
881	3.850156
882	3.850156
883	3.850156
884	3.850156
885	3.850156
886	3.850156
887	3.850156
888	3.850156
889	3.850156
890	3.850156
891	3.850156
892	3.850156
893	3.850156
894	3.850156

The purpose of the history display is to be able to capture all the details of evolution. You'll have noticed that a discussion about the various buttons on the bottom of the evolution window was promised. Here

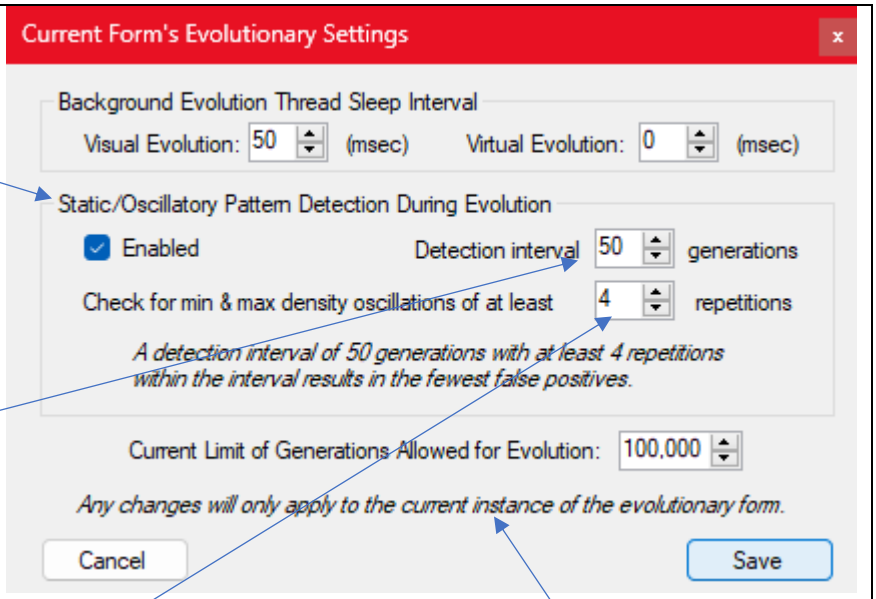
is that discussion in context of why the universe was shown as static at generation 950 when it actually had become static at generation 879 as shown on the previous page. The reason for that is an algorithm for determining when a soup becomes static or periodic was developed that can't be 100% accurate. This algorithm is controlled by settings viewed by pressing the "Evolutionary Settings" button, prior to the beginning of evolution…



…that presents this modal window:

The algorithm is controlled by settings in the screen region labeled "Static/Oscillatory Pattern Detection During Evolution".

The default settings are shown and have been proven by trial and error to be accurate for most CA and PE evolution scenarios. The "Detection Interval" of 50 generations means that the software looks back during evolution at every 50 generations for density patterns that indicate a static or periodic condition of density.

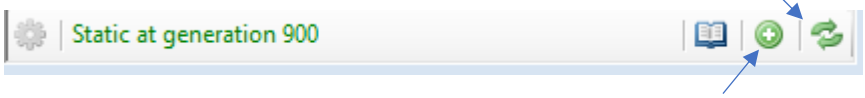


The "Check for min & max density oscillations of at least" numeric entry control's default value of "4" has also been determined as the best value.

Note that in this context, any changes will only apply to this particular instance of evolution.

In the case of the current soup being shown, setting the detection interval to "20" and the repetitions to "2" will result in a detection of the end state at 900 generations. Nevertheless, if absolute accuracy is needed, then examining the density change over the course of evolution using the "Navigation" grid is the method to choose.

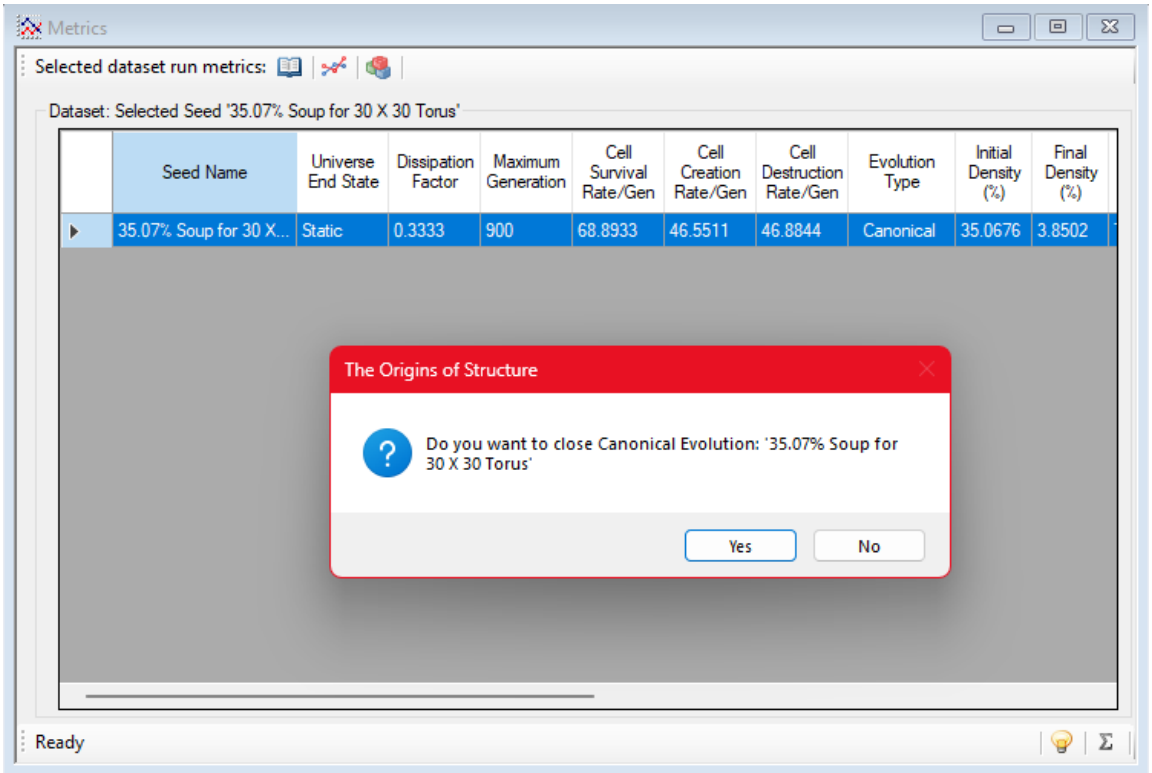
To reset the window to its beginning state without a soup, select the "Reset Form" button.



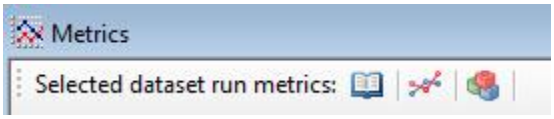
Additional metrics are obtained by selecting the "Add to Metrics Results List" button and a new window will appear underneath a modal dialog discussed in the next section.

Metrics: Summary of Data Runs

This window is designed to hold data from many runs for analysis and comparison purposes and will be discussed in a later section. In this instance, only one data run is shown.



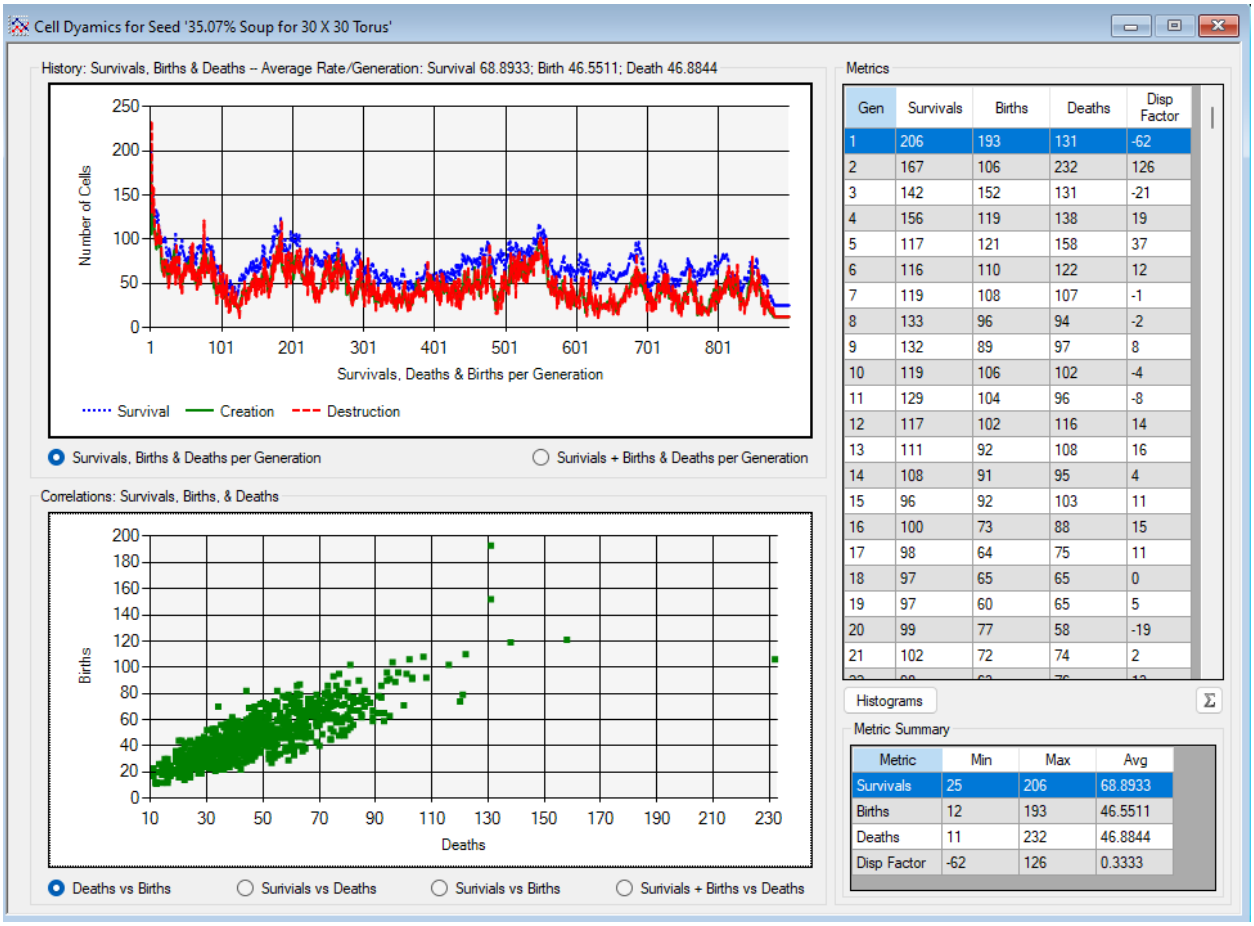
You can dismiss the dialog with a “Yes” and the previous evolution window will close. The data in the grid is discussed in the Life from Ash paper: most columns are self-explanatory and represent a record of the conditions of evolution. Regarding the buttons at the top of the window:



When a row in the grid is selected, these three buttons, from left to right, provide additional metrics: first, Evolution History, previously discussed and second and third, Cell Dynamics and Structures, are discussed on the pages following.

Cell Dynamics

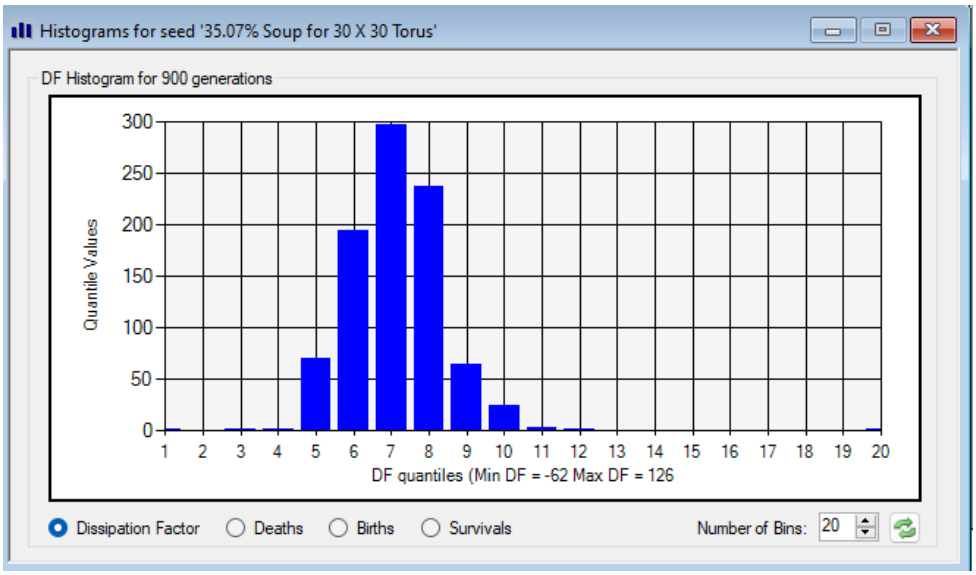
A different look at evolutionary history in terms of the metrics shown in the grid.



Gen	Survivals	Births	Deaths	Disp Factor
1	206	193	131	-62
2	167	106	232	126
3	142	152	131	-21
4	156	119	138	19
5	117	121	158	37
6	116	110	122	12
7	119	108	107	-1
8	133	96	94	-2
9	132	89	97	8
10	119	106	102	-4
11	129	104	96	-8
12	117	102	116	14
13	111	92	108	16
14	108	91	95	4
15	96	92	103	11
16	100	73	88	15
17	98	64	75	11
18	97	65	65	0
19	97	60	65	5
20	99	77	58	-19
21	102	72	74	2

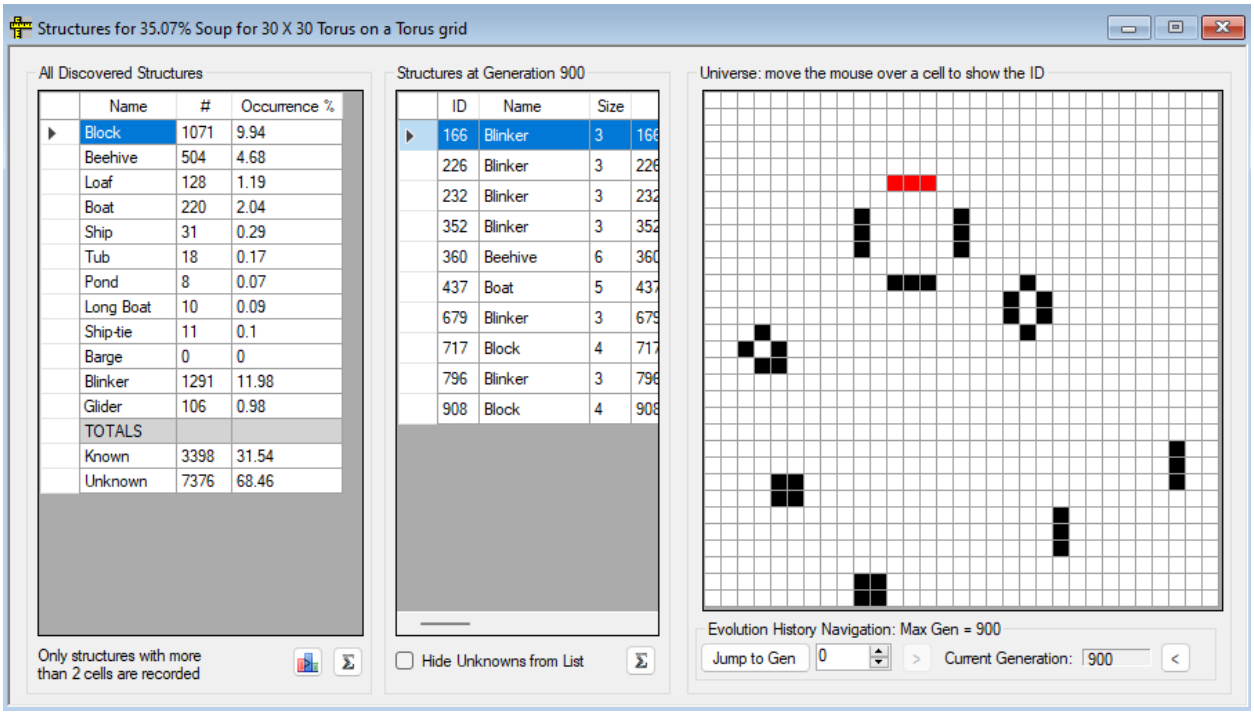
Metric	Min	Max	Avg
Survivals	25	206	68.8933
Births	12	193	46.5511
Deaths	11	232	46.8844
Disp Factor	-62	126	0.3333

The “Histograms” button displays key metrics in a different format:

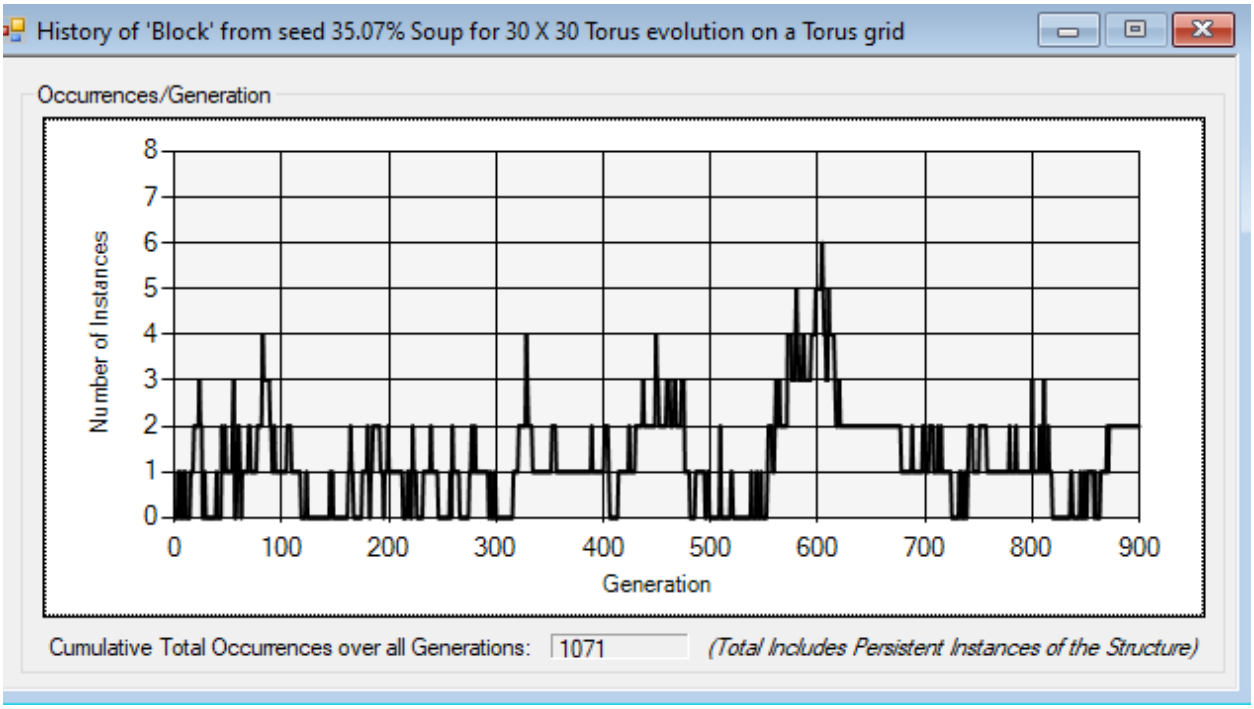


Structures

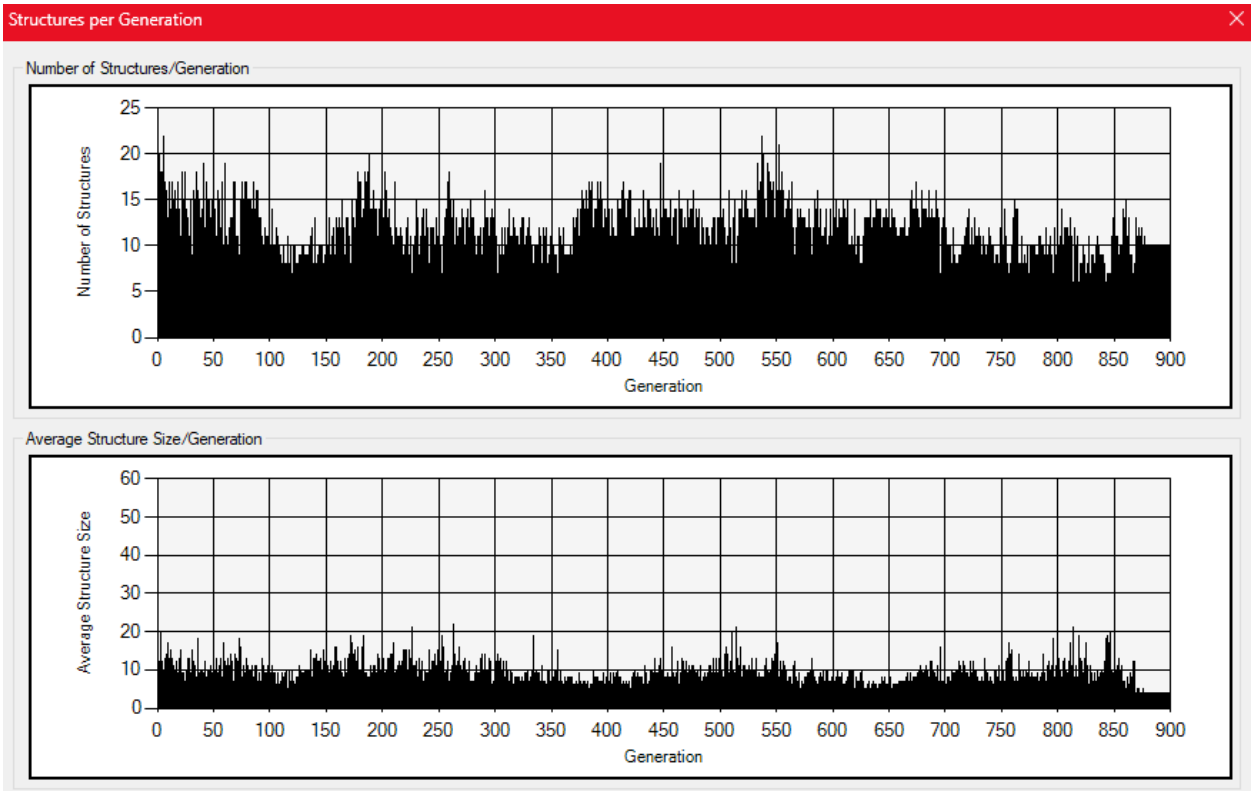
During evolution, a record of the type of patterns that evolve at each generation is shown here.



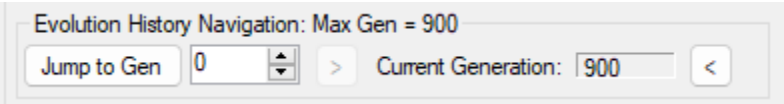
Double-clicking on a grid row in the "All Discovered Structures" region will display this history:



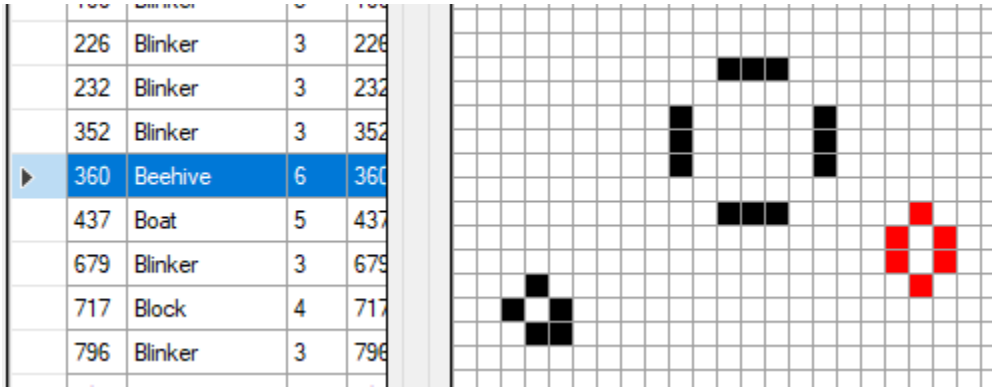
Underneath the structures grid is a button () that when clicked displays a history of structure building in two different formats, shown on the next page.



Seeing structures at each generation is possible using the navigation controls in the lower right-hand region of the main window:

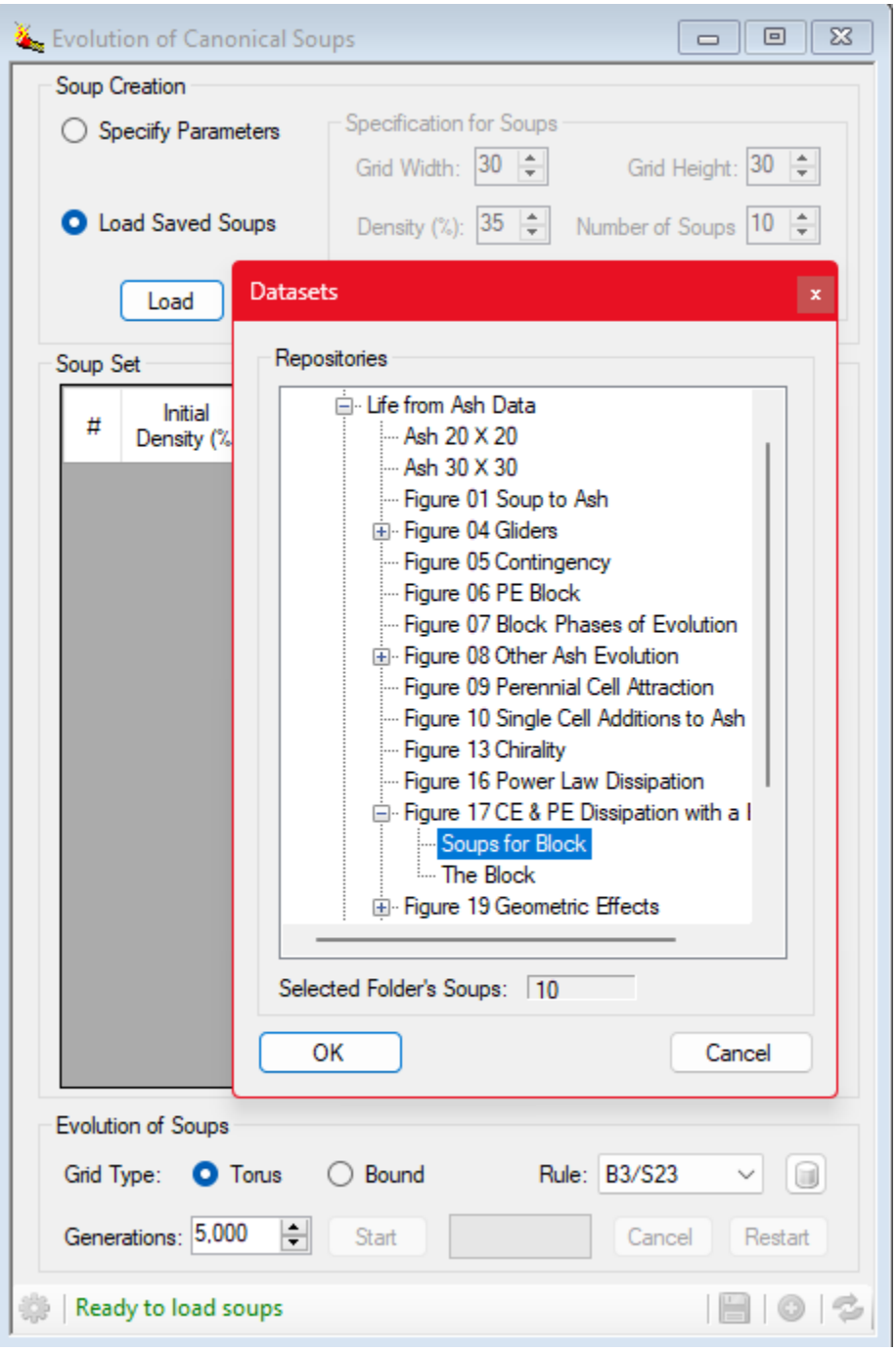


As you move from generation to generation, a structure will be highlighted in red as seen on the previous page. Selecting a different grid row will highlight a different structure.



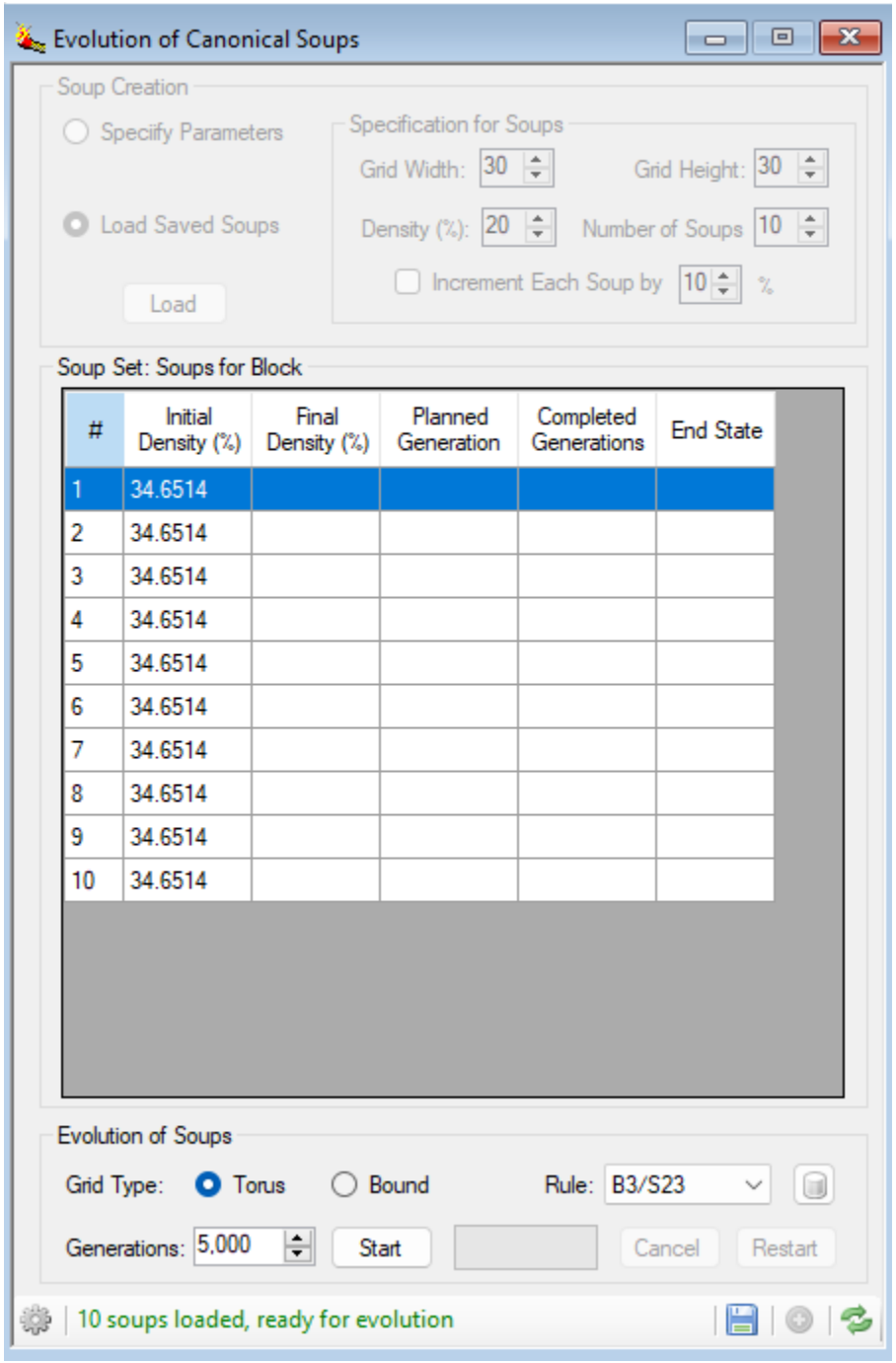
Multiple Canonical Data Runs

From the main menu select “Canonical Evolution\Multiple Canonical Soups”. To view evolution of the CE soups from Figure 17 in the manuscript, select the “Load Saved Soup” option button.

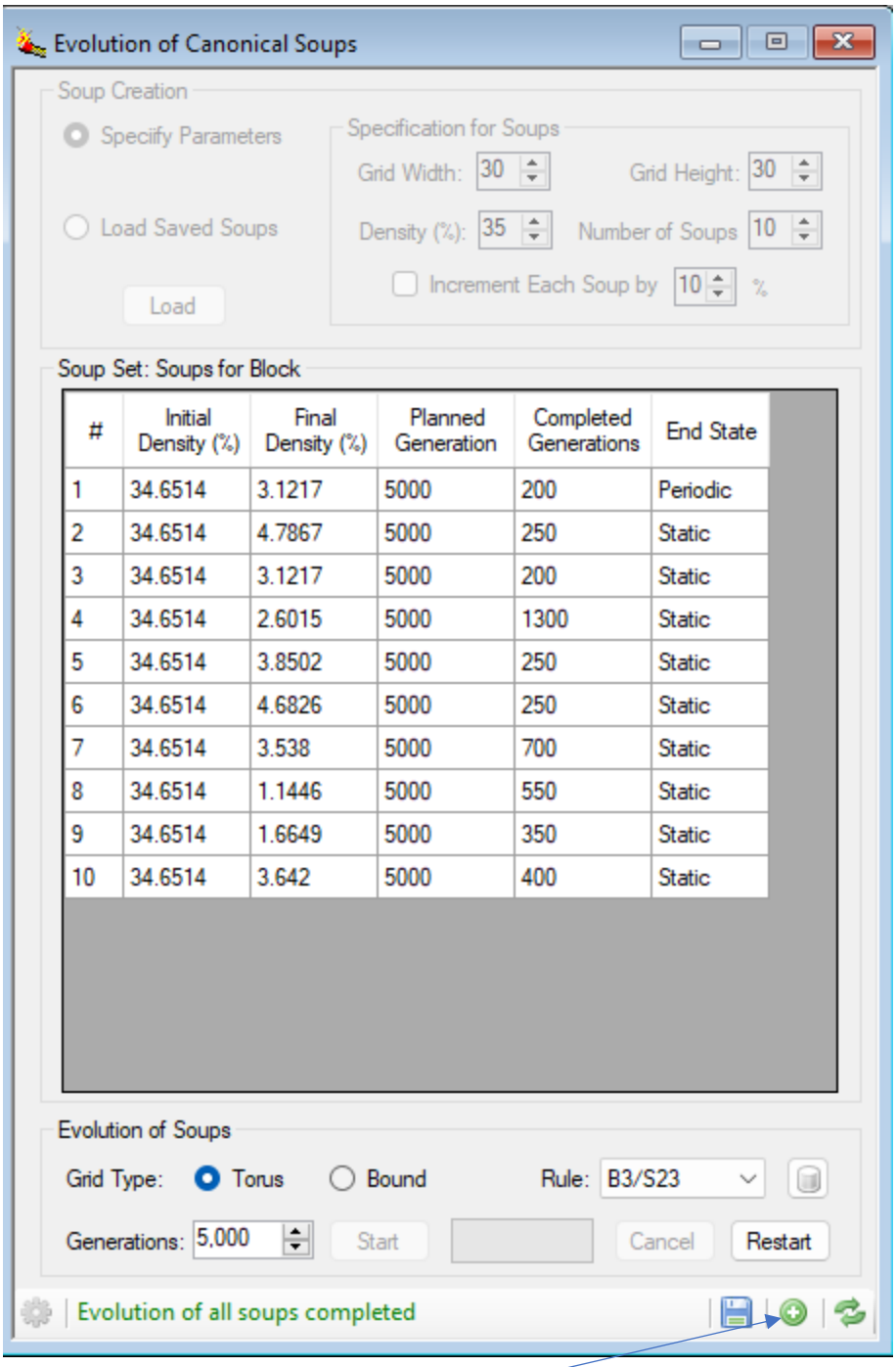


Soups can also be created using the other option button, “Specify Parameters”, and saved to disk using the “Save Soups” button on the bottom tool bar.

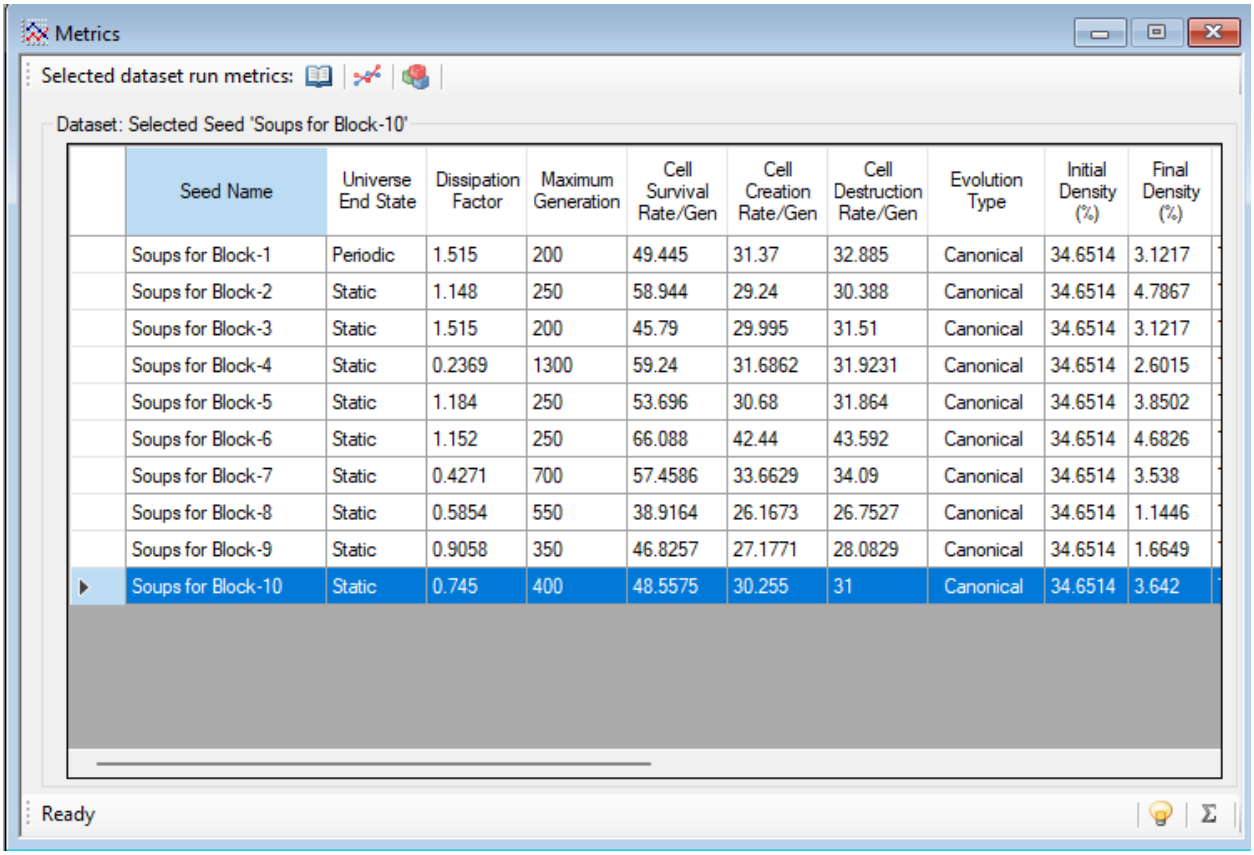
After the soups are loaded, the window will look like this:



Select “Start” and after evolution is completed, the window will look like the following:



Metrics for each soup can be launched from here.

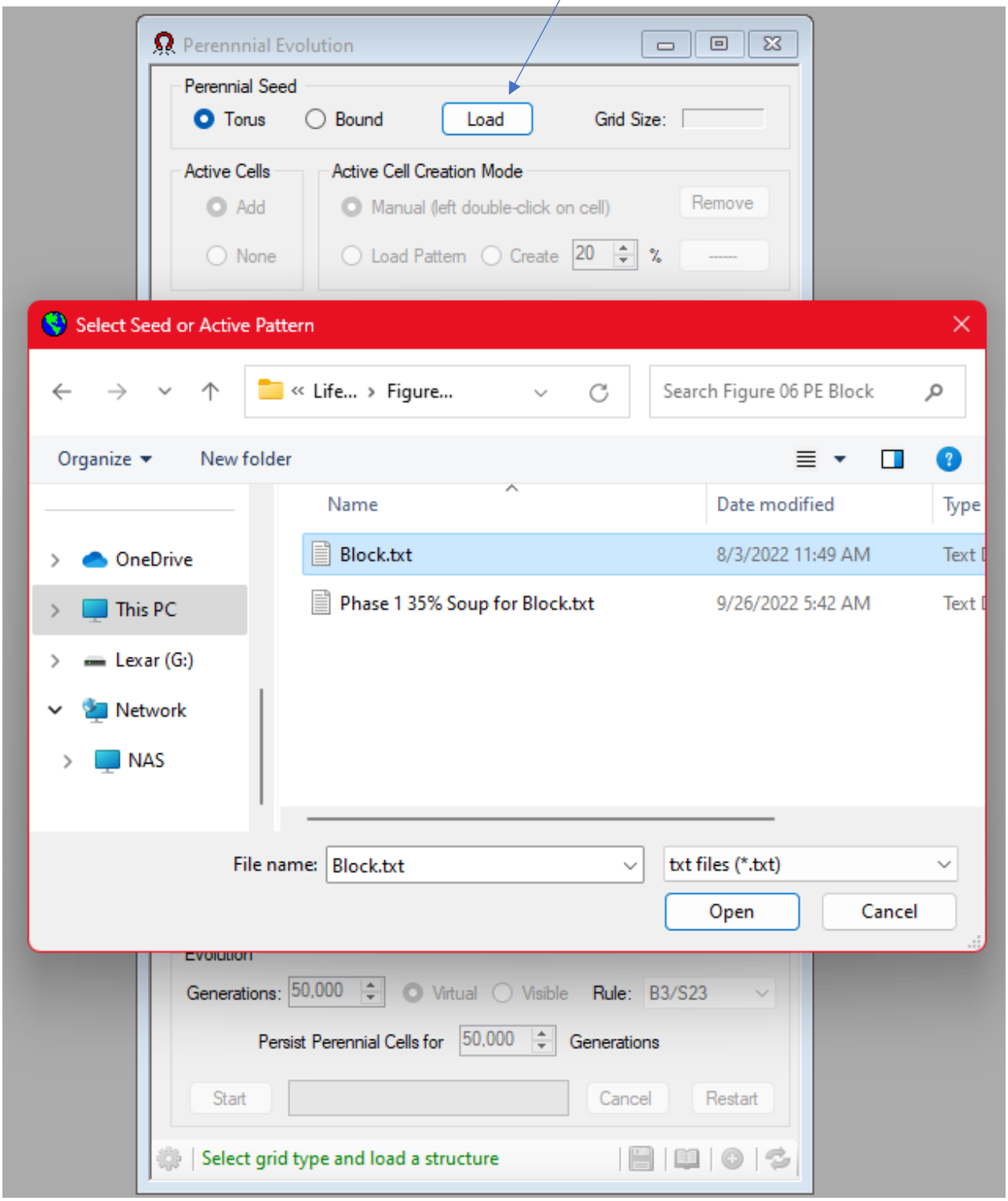


Seed Name	Universe End State	Dissipation Factor	Maximum Generation	Cell Survival Rate/Gen	Cell Creation Rate/Gen	Cell Destruction Rate/Gen	Evolution Type	Initial Density (%)	Final Density (%)
Soups for Block-1	Periodic	1.515	200	49.445	31.37	32.885	Canonical	34.6514	3.1217
Soups for Block-2	Static	1.148	250	58.944	29.24	30.388	Canonical	34.6514	4.7867
Soups for Block-3	Static	1.515	200	45.79	29.995	31.51	Canonical	34.6514	3.1217
Soups for Block-4	Static	0.2369	1300	59.24	31.6862	31.9231	Canonical	34.6514	2.6015
Soups for Block-5	Static	1.184	250	53.696	30.68	31.864	Canonical	34.6514	3.8502
Soups for Block-6	Static	1.152	250	66.088	42.44	43.592	Canonical	34.6514	4.6826
Soups for Block-7	Static	0.4271	700	57.4586	33.6629	34.09	Canonical	34.6514	3.538
Soups for Block-8	Static	0.5854	550	38.9164	26.1673	26.7527	Canonical	34.6514	1.1446
Soups for Block-9	Static	0.9058	350	46.8257	27.1771	28.0829	Canonical	34.6514	1.6649
Soups for Block-10	Static	0.745	400	48.5575	30.255	31	Canonical	34.6514	3.642

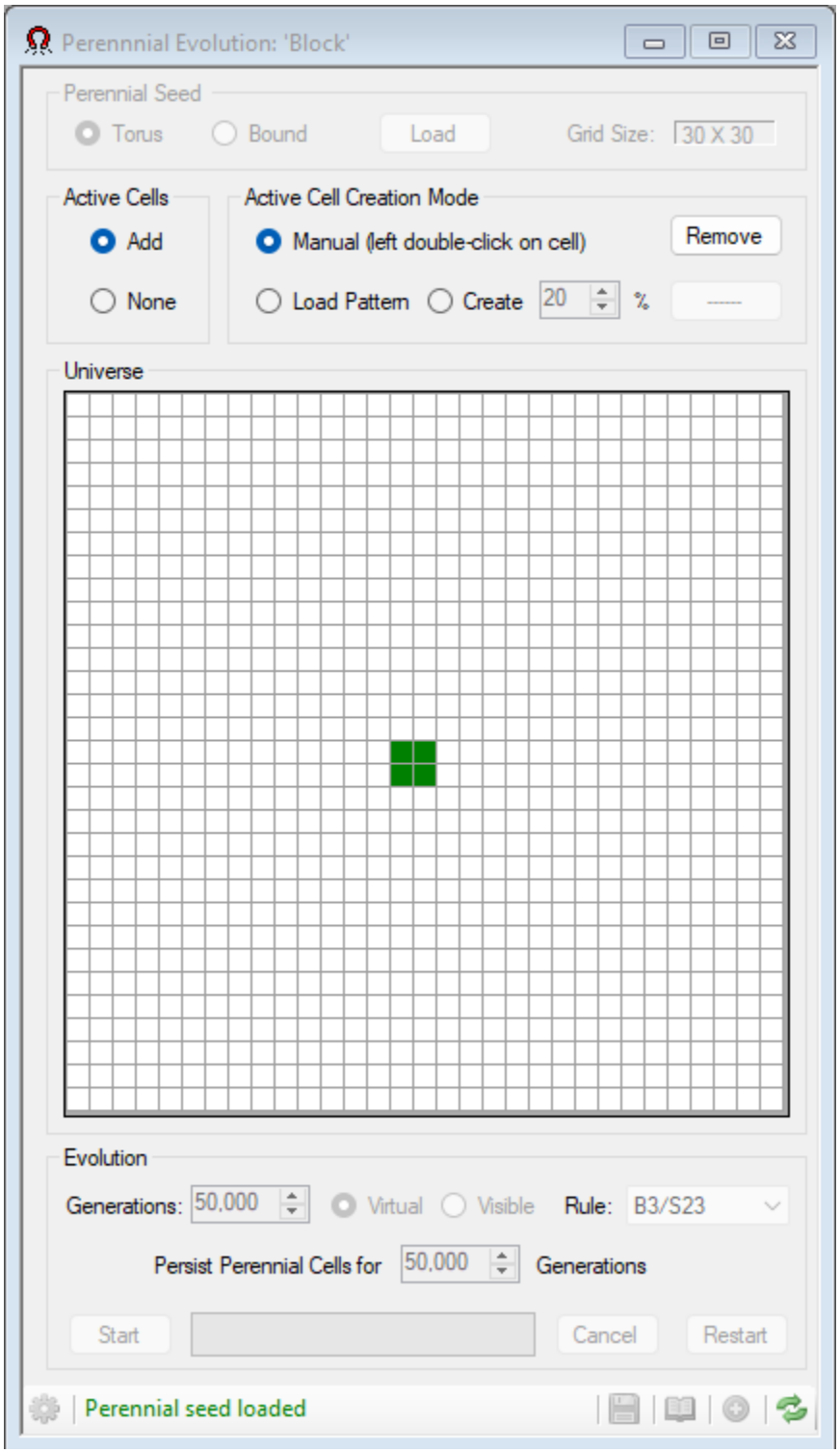
These data runs are part of what is seen in Figure 17 of the paper and illustrate the purpose of the Metrics form as an aggregation method for subsequent analysis.

Perennial Evolution

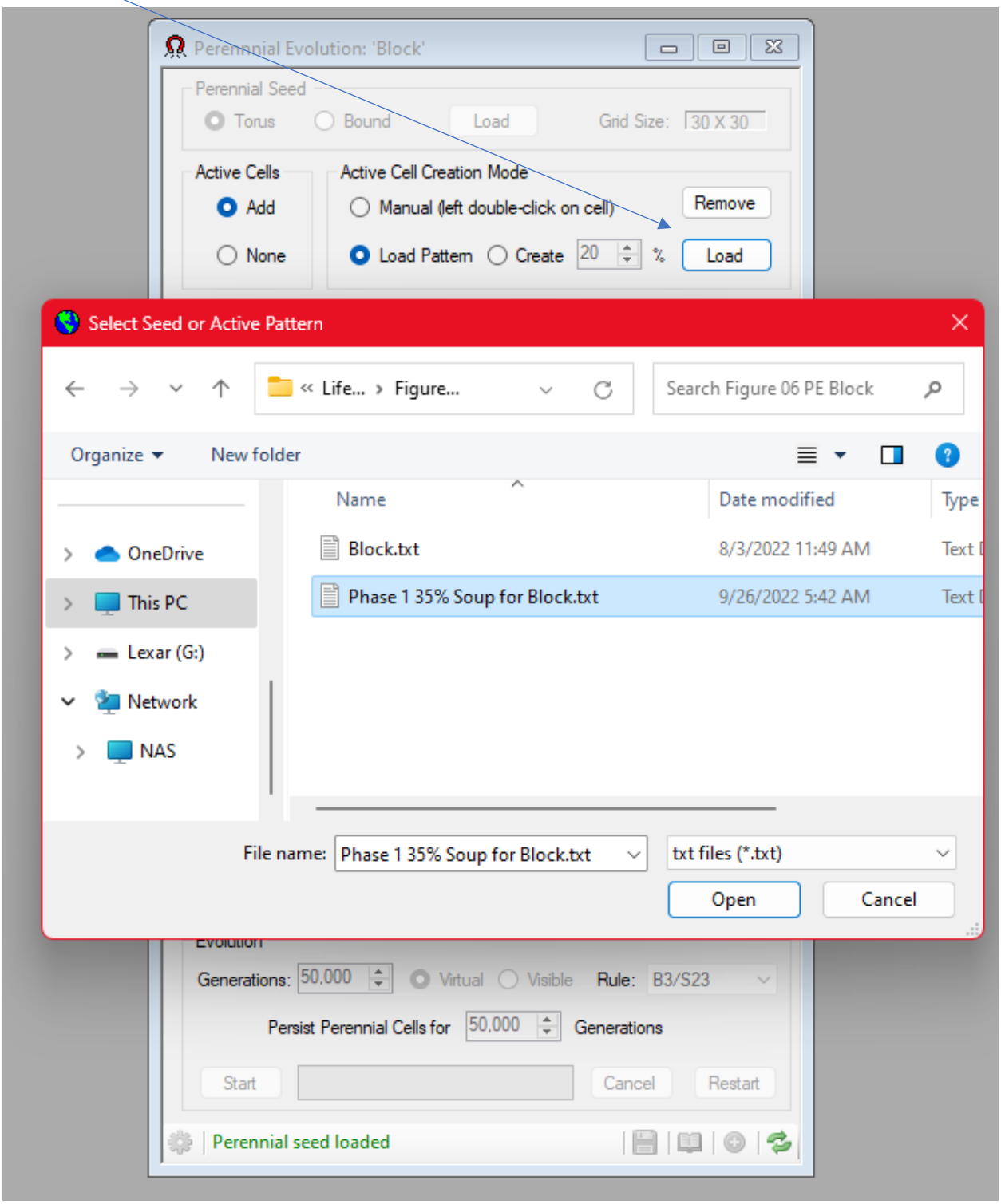
A single PE seed can be launched from the main menu selection Perennial Evolution\Single Perennial Seed. For example, to replicate Figure 6 in the paper, first load the block.



After the block is loaded, the window will look like this:



Next, load the 35% soup for the block.

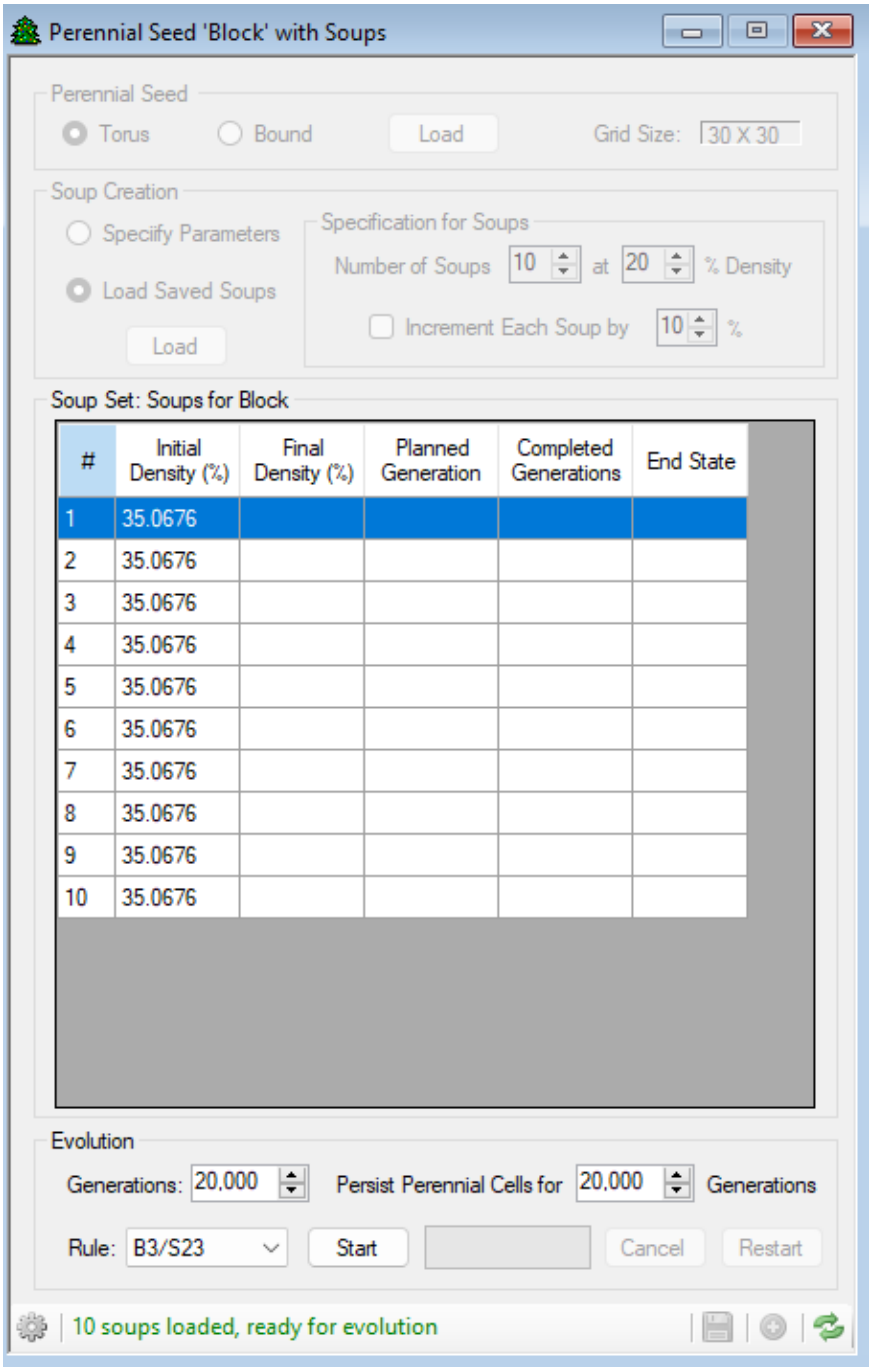


The evolution can now begin.

Select “Start” and you’ll see the data that provides the analysis shown in Figure 6. The “Persist Perennial Cells” numeric control is linked to the “Generations” control and will automatically contain the same value. This feature is for future research and its function is not currently used in the paper.

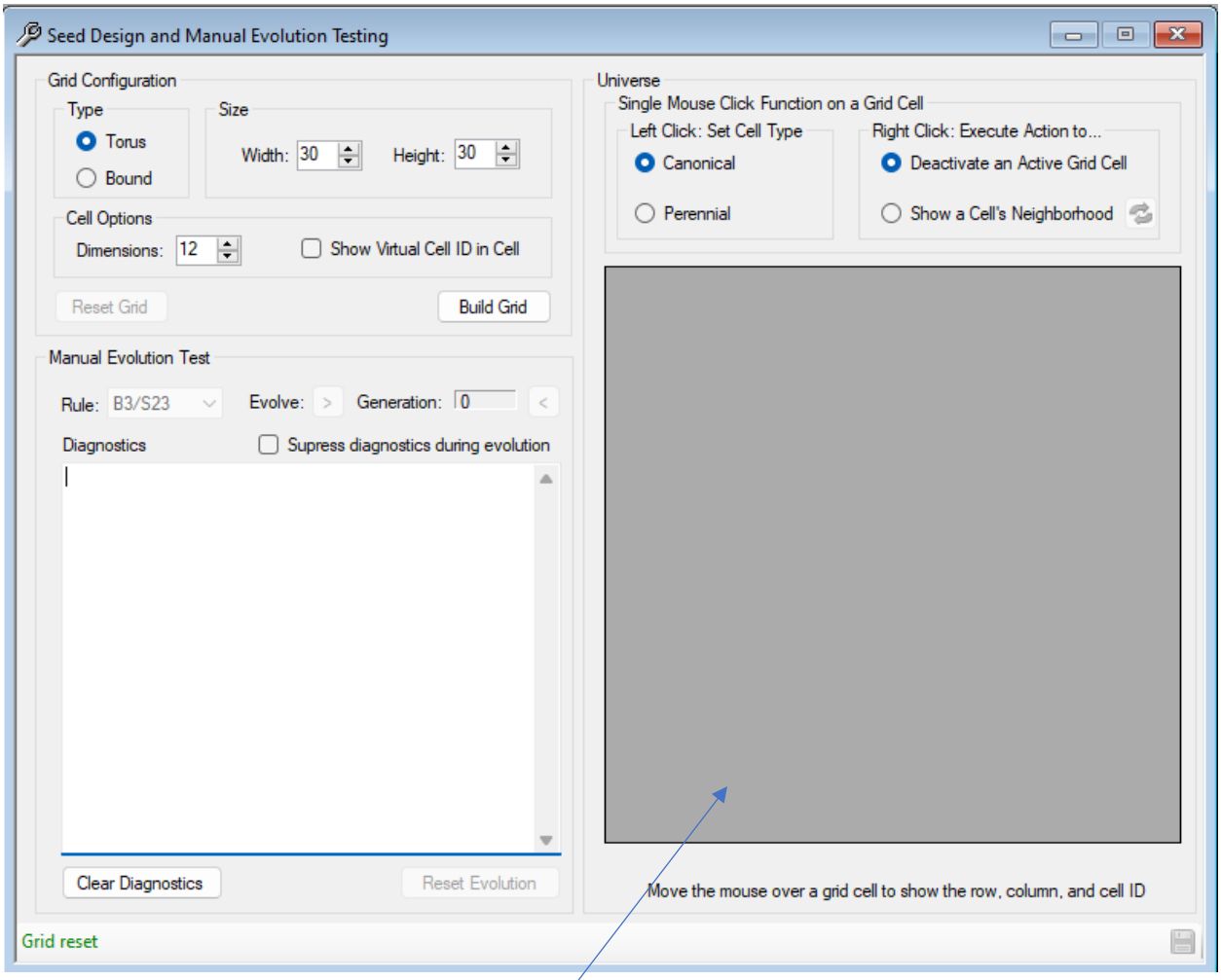
Multiple Perennial Seeds with Soups

The data presented in Figure 17 for the soups evolving as CE was previously shown on page 14. Another part of this data presentation was the soups evolving as PE with an embedded block. Select from the main menu Perennial Evolution\Perennial Seed + Soups, and first load the block from the repository and then the soups. The window should look like this prior to the start of evolution.



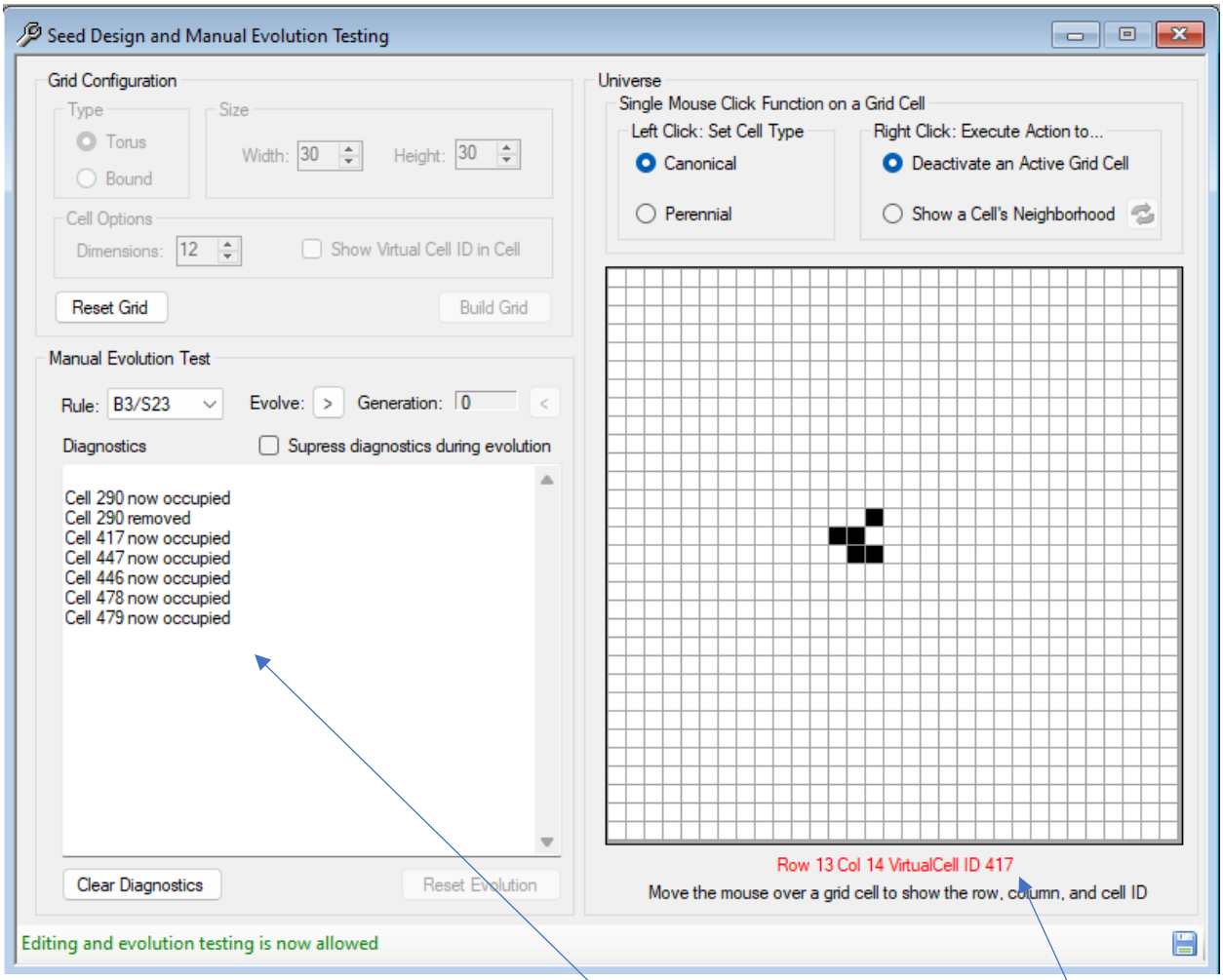
Seed Design

Seeds can be manually designed by selecting from the main menu Seeds\Seed Design and Testing. The window presented is shown below.



Selecting “Build Grid” will create a workspace here.

A seed can be manually evolved from this window such as a right-handed rocket glider.

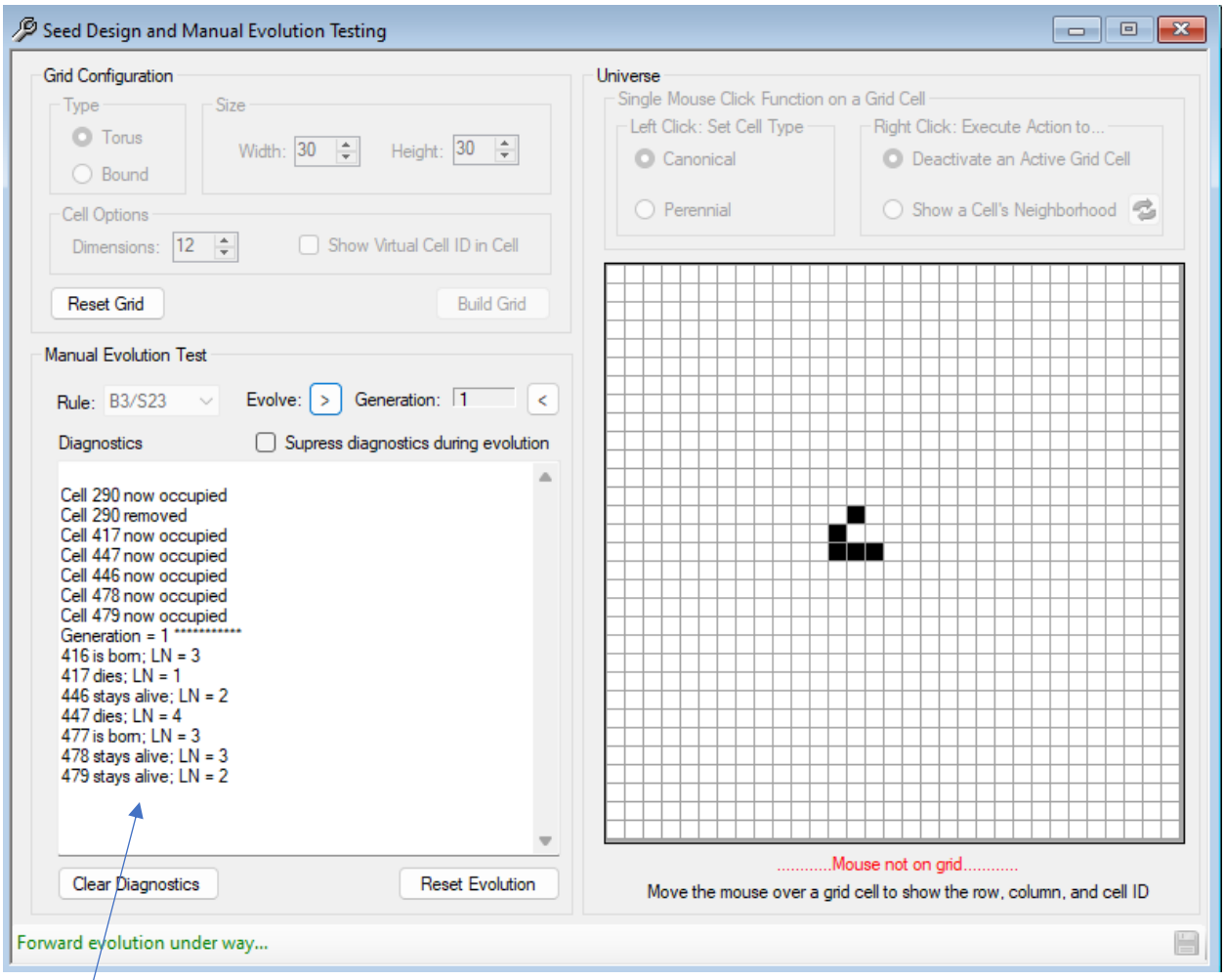


As you create or remove cells, a record is generated here.

As you move the mouse over a cell, its location on the grid will be shown; in this case the uppermost cell had the mouse pointer hovering on it.

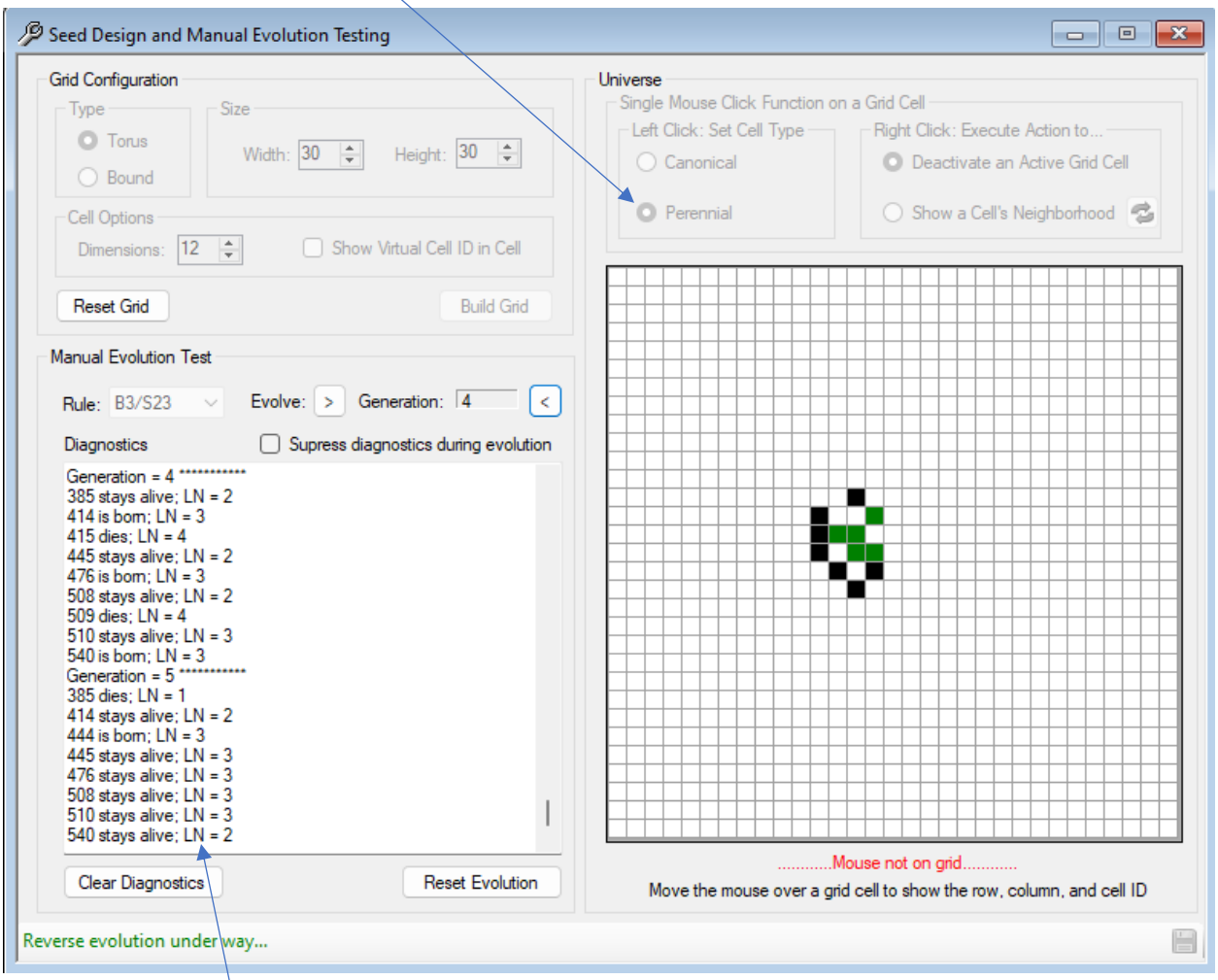
A seed can be saved prior to an evolution, i.e., at generation 0 by using the “Save Design” icon in the lower right-hand portion of the window.

Manual evolution can also be demonstrated, as shown below where the glider evolves by one generation.



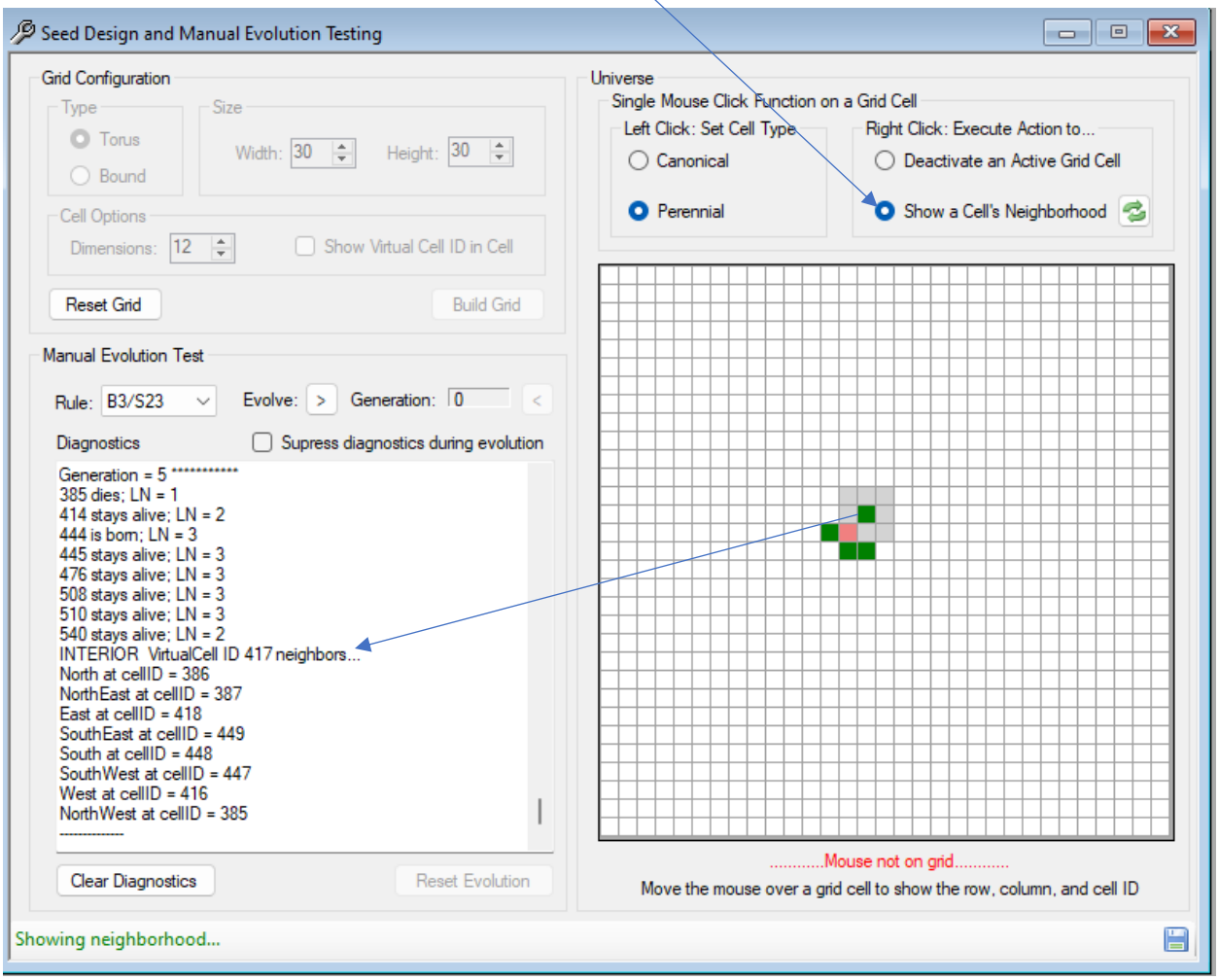
A record of cells created, destroyed, or staying alive is also created.

A perennial seed can also be created, such as a glider that evolves to create new live cells.



The abbreviation “LN” indicates the number of live neighbors for a cell.

The Moore neighborhood of a cell can also be viewed using the right mouse button.

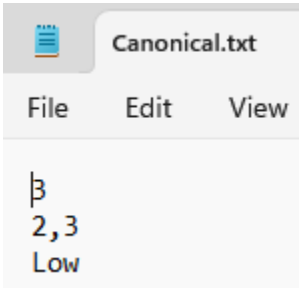


Settings

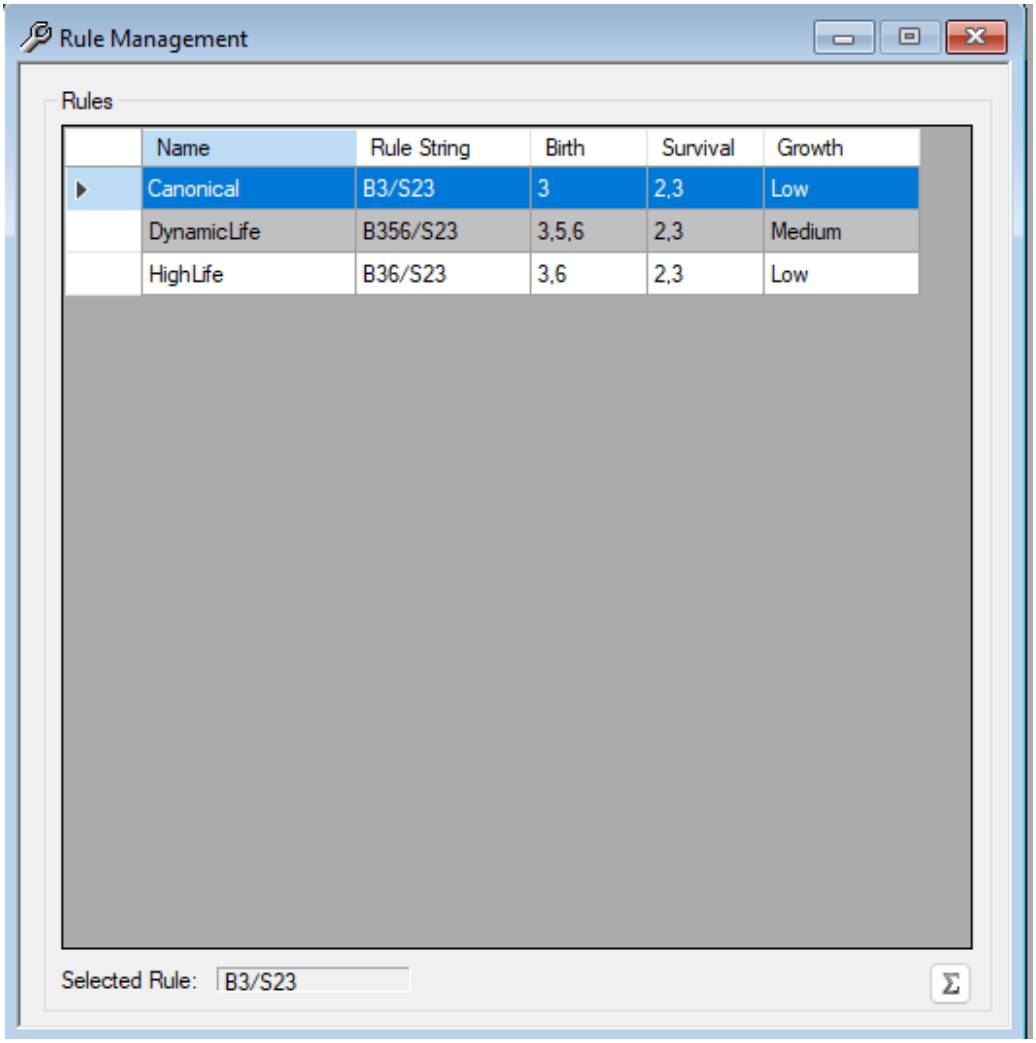
The software is controlled by several categories of settings described below.

Rule Management

Rules are simple text files in the “Rules” installation folder. For example, the canonical rule’s text file, named “Canonical.txt” looks like this in Notepad:

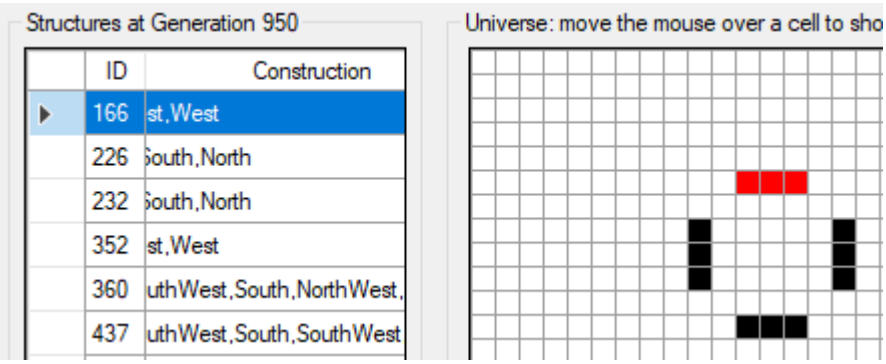


All rules can be viewed from the Settings\Rules menu.



Structures

Referring to the page where structures for the soup shown in Figure 1 of the paper were presented, a region of the window not visible on that page is shown here:

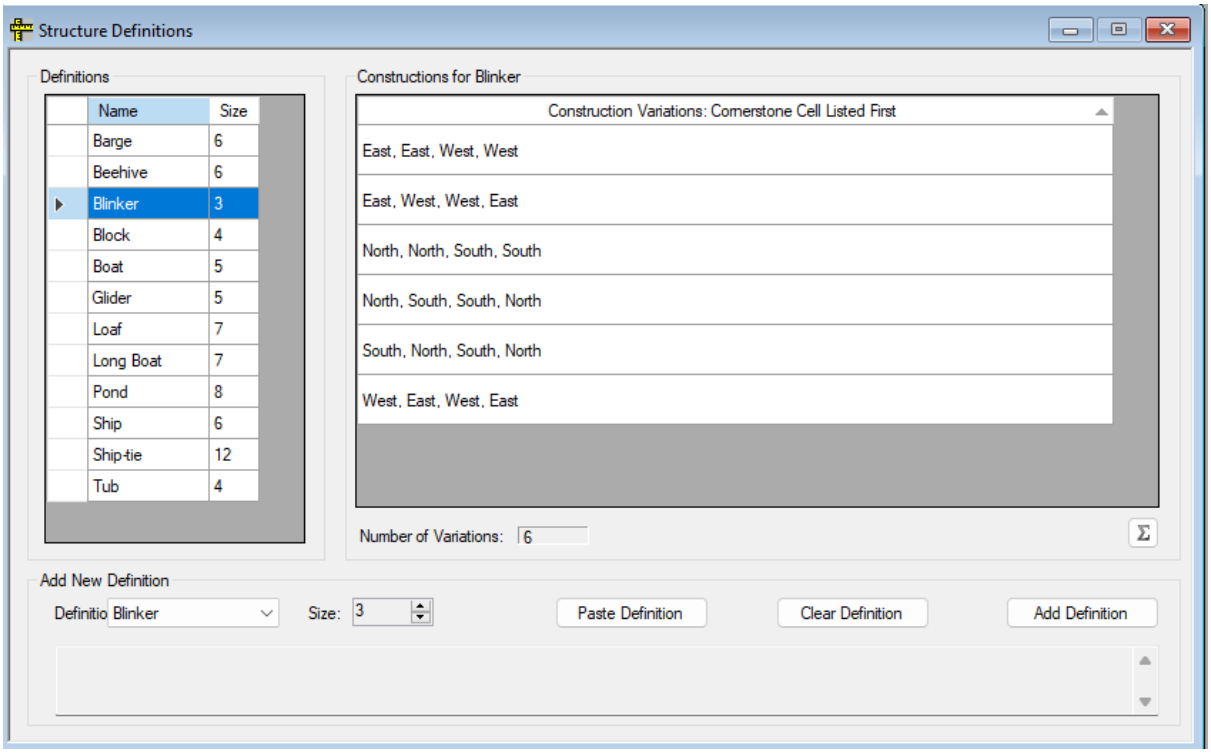


The grid column now visible called “Construction” identifies a how a blinker’s cells are related to each other with respect to the cornerstone cell. The cornerstone for a blinker is seen using the Seed Designer where the virtual cell IDs of each cell are made visible.

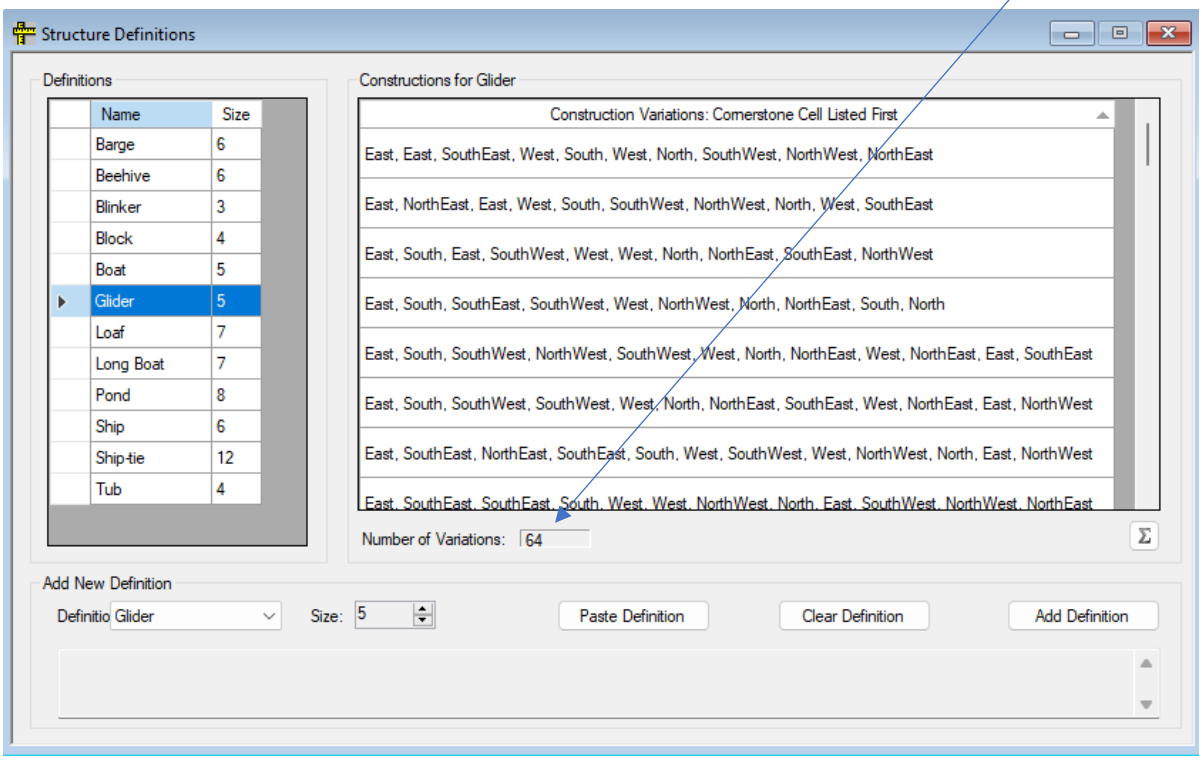
0	1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20	21
22	23	24	25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40	41	42	43
44	45	46	47	48	49	50	51	52	53	54
55	56	57	58	59	60	61	62	63	64	65
66	67	68	69	70	71	72	73	74	75	76
77	78	79	80	81	82	83	84	85	86	87
88	89	90	91	92	93	94	95	96	97	98
99	100	101	102	103	104	105	106	107	108	109
110	111	112	113	114	115	116	117	118	119	120

In this case, on a 10 X 10 grid, the blinker’s cornerstone is cell 48. A cornerstone is always the lowest numeric value of a cell among a given connected series of cells in this software.

Selecting from the main menu Settings\Structures shows a list of the possible constructions for the top ten ash as well as blinkers and gliders for both bound and torus gird types. This screen is shown on the next page.

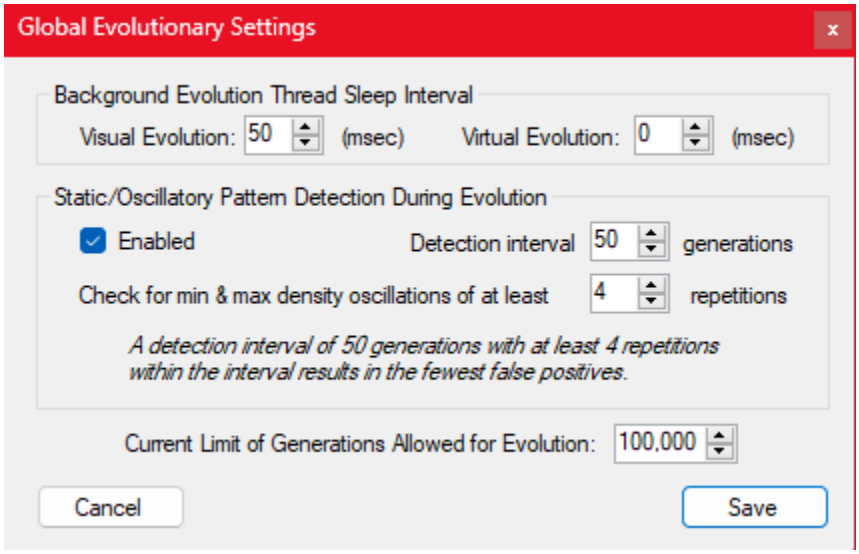


This tool was used during development to record the variety of constructions that can appear during evolution. Gliders are interesting in that they have the greatest number of possible constructions.



Global Evolutionary Settings

This window was discussed on a previous page in the context of varying the settings for a particular instance of evolution. Globally, the settings screen has this application modal presentation and will modify settings for all instance of canonical and perennial evolution.



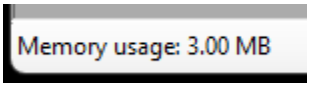
While a limit of 100,000 generations is allowed, this limit is not often reached for grid sizes of 30 X 30 except for some perennial evolutions that can persist for quite some time. Often, as the number of generations surpasses 50,000 generations on a desktop computer, even one such as the development machine with 64 GB of memory, it will be forced to use virtual memory on the hard disk and evolution time can become lengthy. In this case you may see, from time-to-time the dreaded "Not Responding" modification in the main window's title.

You can wait for this to clear while the computer utilizes virtual memory or force a closure of the application using the task manager if necessary.

Memory

As a way of monitoring memory usage, the main menu selection “Memory” has two functions:

(1) Show Memory: this will populate the status text in the lower left-hand corner of the MDI window with the current usage such like this…



…and it will correspond to the memory being used by the current evolution window, assuming such a window is instantiated, in the lower right-hand corner…

…that appears prior to the beginning of an evolution. When evolution is underway, this status will change …

After evolution is finished, the status will show, for example…

When an evolution form is closed, you’ll see a message in the lower left-hand corner showing that memory is being cleared.

(2) Clear Memory: this will clear any memory that is not currently in use and rarely needs to be used. Most windows automatically clear their memory usage when closed. However, the “Metrics” window that may be present and hold the results of multiple data runs will retain a large share of system memory until it is closed.