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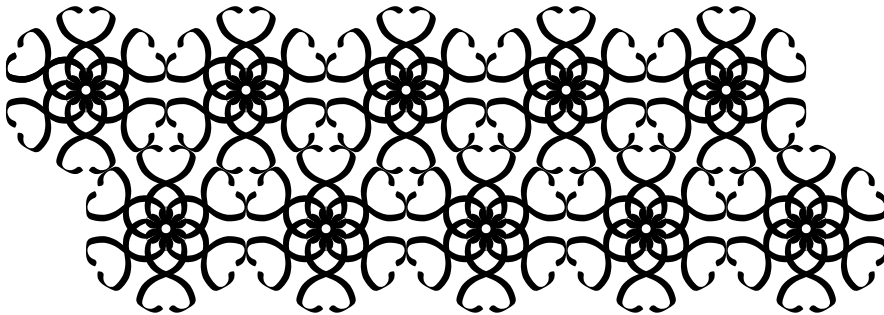
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Chapter 18. Tiling


Tiling or tessellation is the covering of a surface with the repeated use of the same shape tile. A typical example is the tiling in a bathroom. In Inkscape, this concept is expanded to include a multitude of options including progressively changing the tile size, spacing, and orientation.

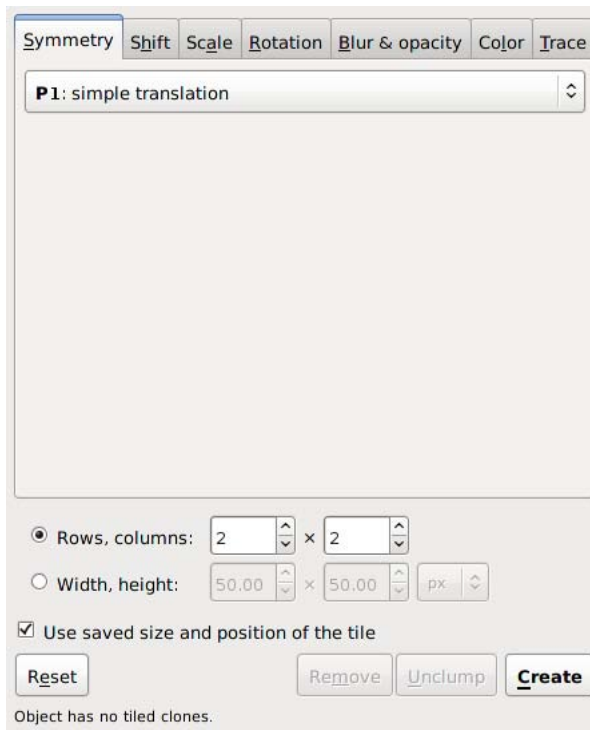
The tiles are in reality just clones of the source tile or object. Thus the same methods that apply to clones apply to tiles. (See the section called *Clones* in Chapter 4, *Editing Basics*.)

While random use of the *Tile Clones* dialog can produce exquisite patterns, it is useful to understand the fundamentals of tessellation in order to have more control over the final design.



An example of using the *Tile Clones* dialog with a simple calligraphic stroke and the *P6M* symmetry group (see text).

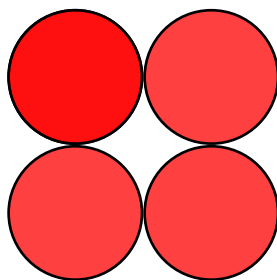
To construct a tiling, open up the *Create Tiled Clones* dialog (Edit → Clone →  Create Tiled Clones...).



The *Tile Clones* dialog with no objects selected.

At the bottom of the dialog is a fixed section where you can choose the size of the tiling either by the number of rows and columns or by the width and height of the area you wish to cover. The terms *Rows* and *Columns* are only really appropriate for tiling of rectangular tiles (see below). Checking the “Used saved size and position of the tile” forces the tiling to use the size and position of the base tile at the last time the tile was used in a tiling. This preserves the spacing between tiles if the *bounding box* has changed due to editing the base tile. Clicking on the *Reset* button resets most of the entries under the tabs to their default values. The *Remove* button can be used to undo a tiling when the base tile is selected. The *Unclump* button can be used to spread out the clones in a somewhat random fashion (can be repeated). And, finally, the *Create* button creates the tiling.

With a circle and the default values (P1 symmetry, two rows and two columns), you will get the following tiling:



The simple tiling of a circle. The symmetry is "P1" and there are two rows and two columns.

The circle has been replicated four times in two rows and two columns. The original circle is still there, under the top-left cloned circle. The *bounding box* of the circle has been used as the base tile size.

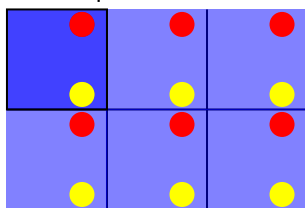
This example is not so interesting, but there are many options under the dialog's tabs that can produce many interesting effects. Each tab will be covered in turn in the following sections.

Symmetry Tab

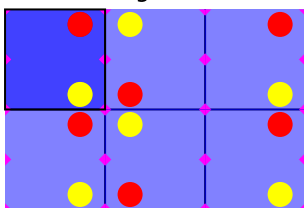
The *Symmetries* tab is at the heart of the tiling process. Understanding the different symmetries is necessary to have full control over the outcome of a tiling. The symmetry of the tiling is selected from the pull-down menu under the *Symmetries* tab (see above figure).

There are three regular geometric shapes that can be replicated to cover a surface completely (without gaps or overlaps). These shapes are: triangles, rectangles (parallelograms), and hexagons. A complete set of tiling symmetries requires taking these shapes and adding rotations and reflections. It is known that there are 17 such tiling symmetries. (See: Wikipedia entry [http://en.wikipedia.org/wiki/Wallpaper_group].) All 17 symmetries are included in the Inkscape *Create Tiled Clones* dialog. The symmetries are shown next.

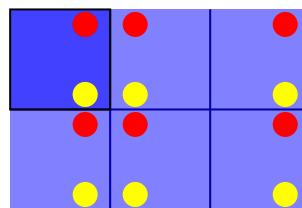
P1: Simple Translation



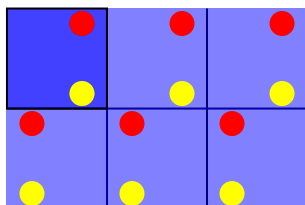
P2: 180 Degree Rotation



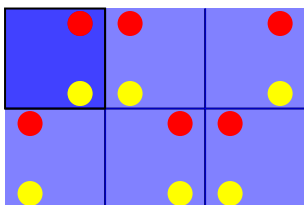
PM: Reflection



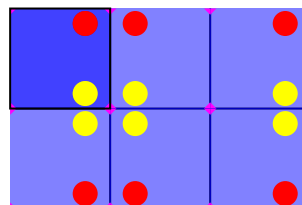
PG: Glide Reflection



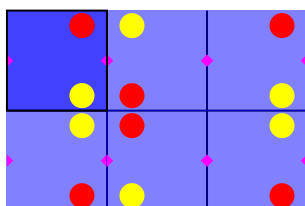
CM: Refl. + Glide Refl.



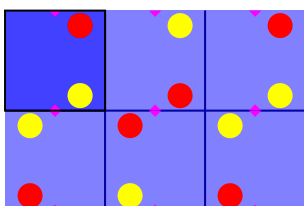
PMM: Refl. + Refl.



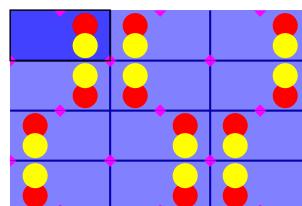
PMG: Refl. + 180 Rot.



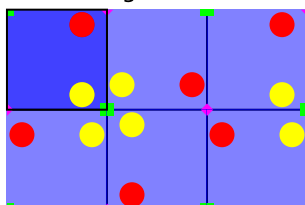
PGG: Glide Refl. + 180 Rot.



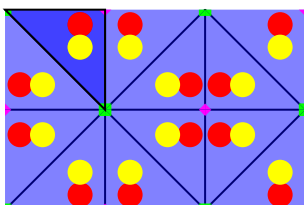
CMM: Refl. + Refl. + 180 Rot.



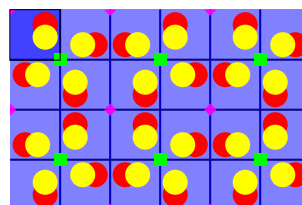
P4: 90 Degree Rotation.



P4M: 90 Rot + 45 Refl.

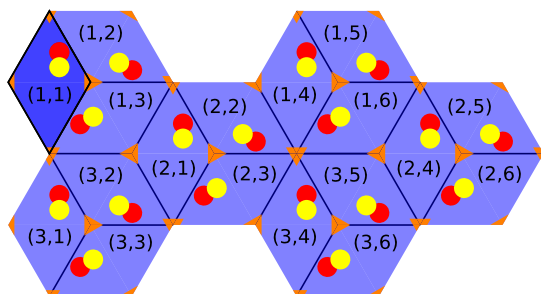


P4G: 90 Rot. + 90 Refl.

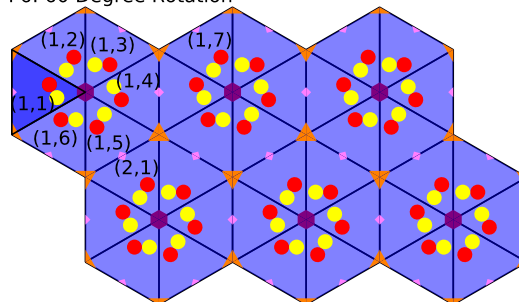


Tilings based on a rectangle tile (or 45-45-90 degree triangle). The outlined dark blue tile is the basic unit. Red and yellow dots show the reflection and rotation symmetries. Points of twofold and fourfold rotational symmetry are shown by pink diamonds and green squares, respectively. The P1 and P2 symmetries also work with parallelograms.

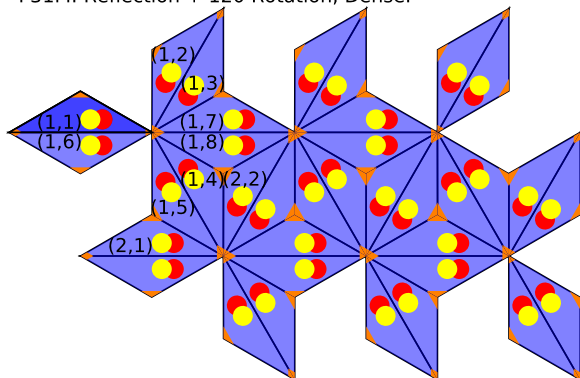
P3: 120 Degree Rotation.



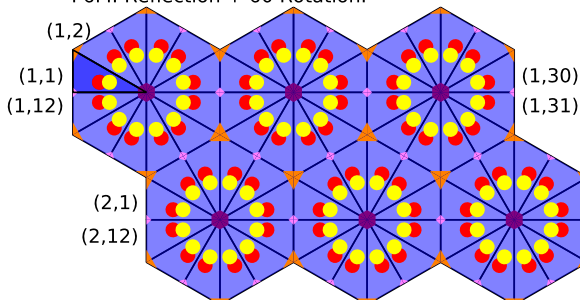
P6: 60 Degree Rotation



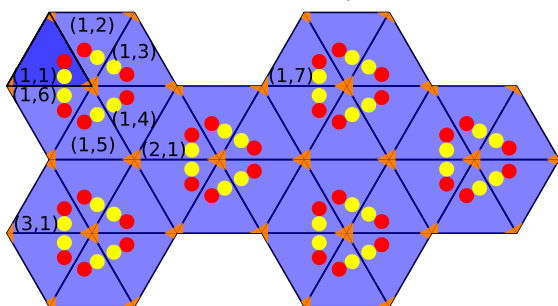
P31M: Reflection + 120 Rotation, Dense.



P6M: Reflection + 60 Rotation.

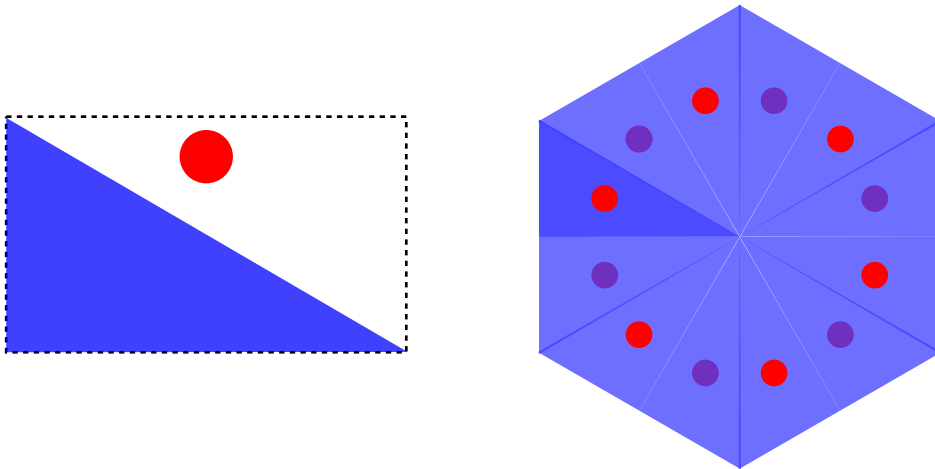


P3M1: Reflection + 120 Rotation, Sparse.



Tiling based on regular subdivisions of a hexagonal. The outlined dark blue tile is the basic unit. All tiling have points of threefold rotational symmetry (orange triangles). Two also have twofold and sixfold rotational symmetries (pink diamonds and purple hexagons). The pairs of numbers indicate the row and column numbers.

The basic tile for each of the 17 symmetries is shown in dark blue in the preceding figures. Inkscape uses the *bounding box* of an object to determine the basic tile size. For rectangular base tiles, the *bounding box* corresponds to the base tile. However, for triangular base tiles, the base tile covers only part of the *bounding box* area. This can result in tiles “overlapping” if an object extends outside the base tile shape (but is still within the *bounding box*) as in the tiling in the introduction to this chapter. Overlapping can also occur if the base tile is altered after the tiles are positioned.



On the left is a triangle and circle that are grouped together. The triangle corresponds to the base tile for a P6M symmetry. Note that the red circle is outside the base triangle but is still within the *bounding box* of the group (and triangle). On the right is a P6M tiling with the triangle and circle. Note how the red circle ends up above some but below other triangles as determined by the order in which the tiling is made.

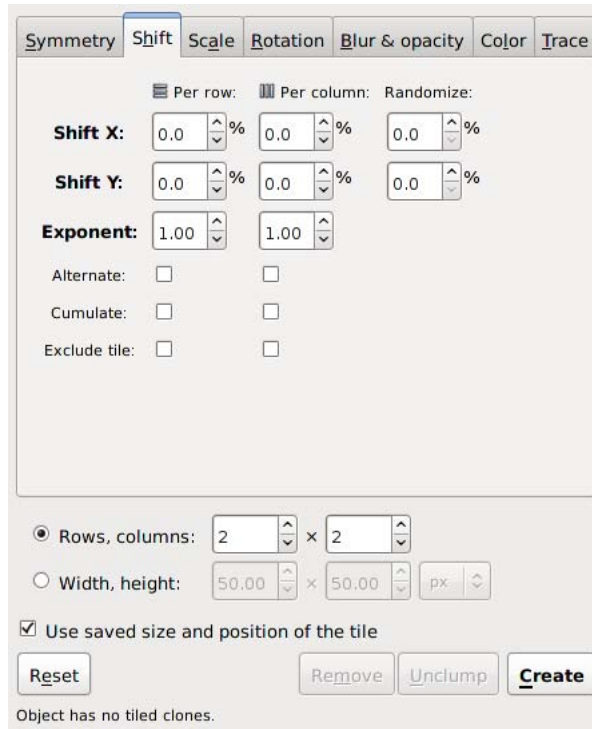
As of v0.46, Inkscape always uses the *Geometric bounding box* to determine the tile size. This avoids problems when creating a triangular tile with a *Stroke* where the *Visual bounding box* doesn't have the same width to height ratio as the *Geometric bounding box*.

If you need to adjust the base tile size after having creating a tiling, you can use the *XML Editor* dialog to change the parameters “inkscape:tile-h” and “inkscape:tile-w” (these will appear after you have cloned the object and are used only if the *Use saved size and position of the tile* button is checked).

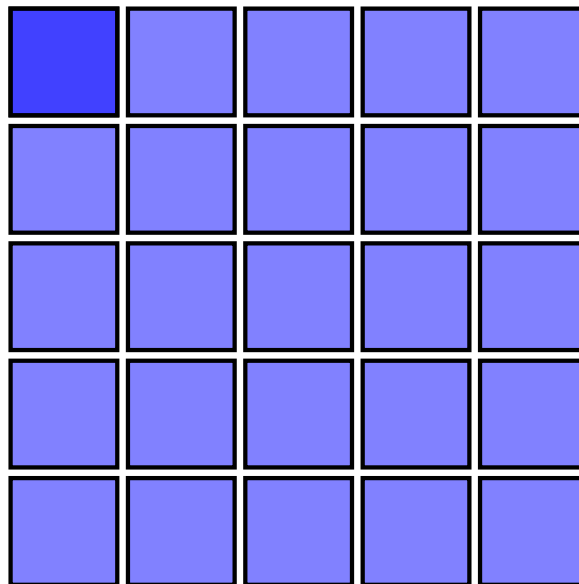
Shift Tab

The *Shift* tab allows one to vary the spacing between tiles. With the default parameters, rectangular tiles are arranged so that their *Geometric bounding boxes* are touching. The following options are available to add or subtract space between the tiles:

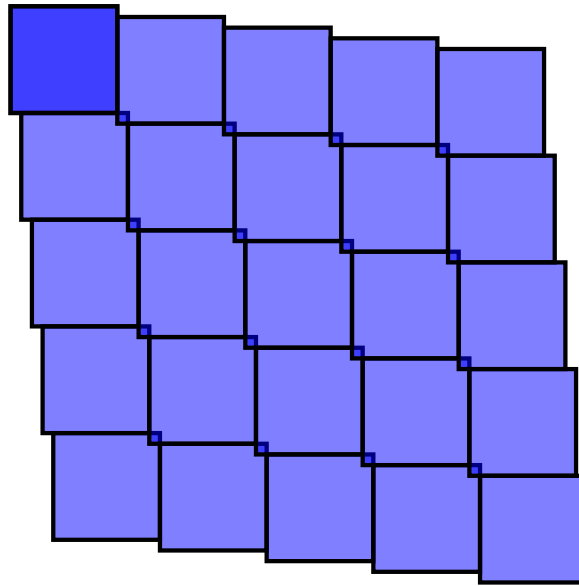
- *Shift X, Shift Y*: Adds (or subtracts) to the tile spacing in units of *bounding box* width and height. A random factor can also be added.
- *Exponent*: Changes the exponent factor z so that position of each tile is x (or y) = $(1 + \text{“shift”})^z$.
- *Alternate*: The shift alternates between being added and subtracted.
- *Cumulate*: The previous shift is added to the new shift. For example, if there was a *Shift X* of 10%, normally the space between subsequent tiles would be 10%, 20%, 30%, and so on. With this option, the shifts become 10%, (10+20)% (10+20+30)%, etc. This is useful when one is also scaling the tiles to keep the tile spacing constant. (See the *Scale Tab* section for an example.)
- *Exclude tile*: The tile width or height is excluded in the calculation of tile spacing. This is useful when using the *Rotation* option to put tiles on a circle. In this case, it is a shortcut for specifying a -100% shift.



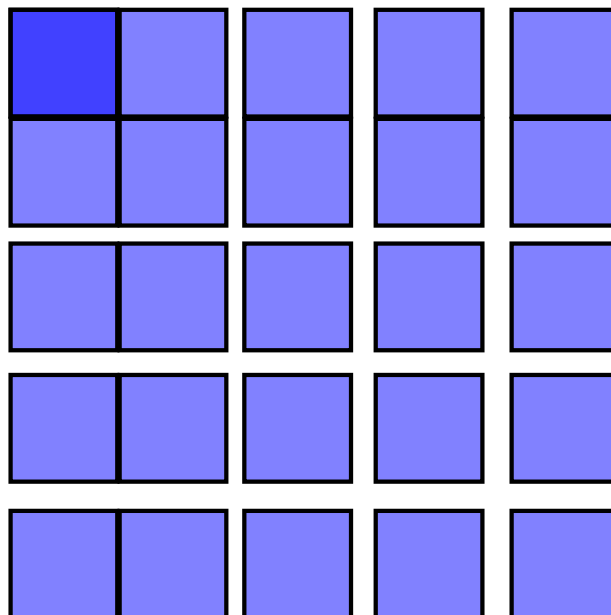
The *Shift* tab of the *Tile Clones* dialog.



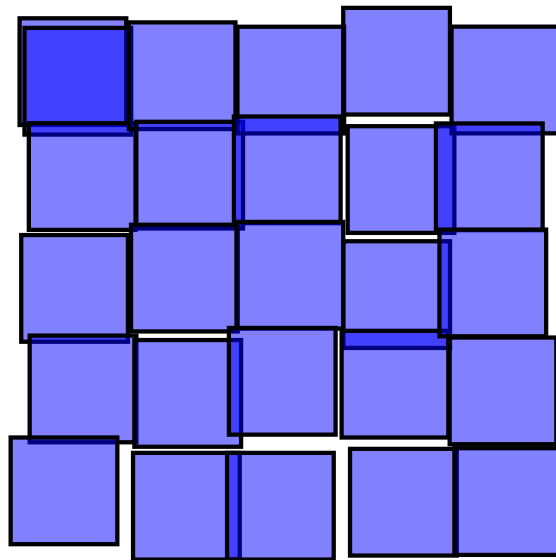
A P1 symmetry tiling with a constant shift of 10% (of the *bounding box*). There is an *x* shift for each column and a *y* shift for each row.



A P1 symmetry tiling with a constant shift of 10% (of the *bounding box*). There is a y shift for each column and an x shift for each row.

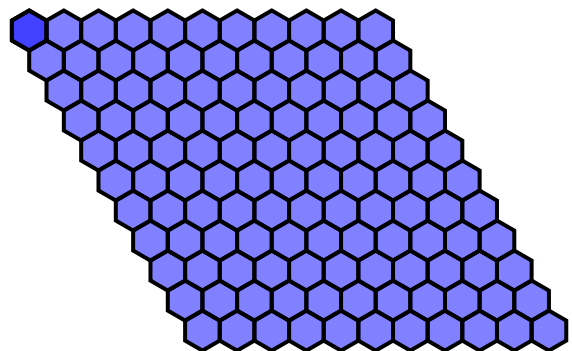
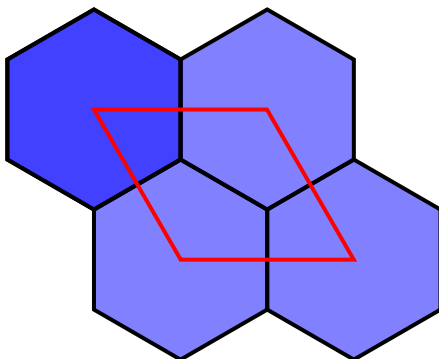


A P1 symmetry tiling with an exponential shift of 1.1 (2% shift in x and y).



A P1 symmetry tiling with a random shift of 10% (of the *bounding box*) in both x and y .

Question: What is the symmetry of closely packed hexagons? The answer is P1 as can be seen below. One can use this fact to trivially generate the board for the game Hex [http://en.wikipedia.org/wiki/Hex_%28board_game%29] invented independently by the mathematicians Piet Hein and John Nash.

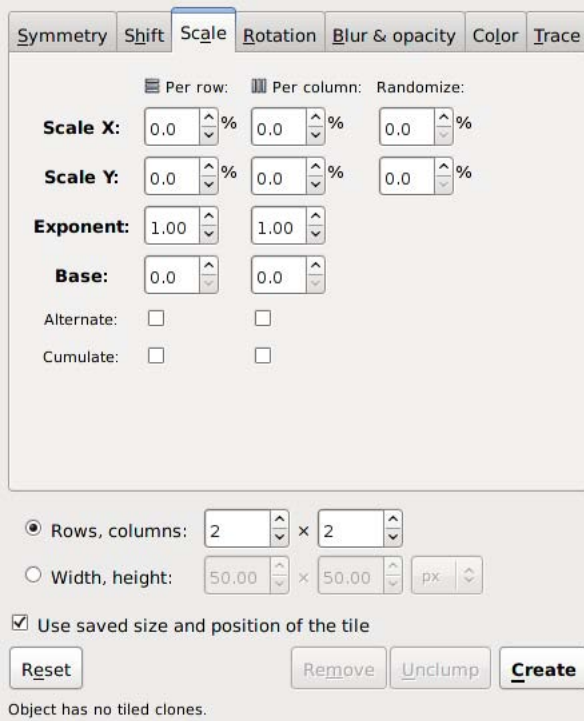


Closely packed hexagons have a P1 symmetry tiling as shown on the left. On the right is the board for the game Hex. To generate both tilings, a hexagon was tiled using a shift in x of 50% and a shift in y of $-25%$ per row.

Scale Tab

The *Scale* tab allows one to increase or decrease the size of the tiles depending on the row and column position. The following options are available to scale tiles:

- *Scale X, Scale Y*: Scales each tile in terms of percentage. A random factor can be added.
- *Exponent*: Scale each tile with an exponential factor. The nominal scaling S becomes S^{exponent} .
- *Base*: Used to create a logarithmic spiral along with *Rotation*. The nominal scaling S becomes base^{S-1} unless *base* is one in which case scaling remains unchanged. Use a value less than one for a converging spiral and a value greater than one for a diverging spiral. A true logarithmic spiral would use a base of $e = 2.718$ (or $1/e = 0.368$). See the *Tile Tricks* section for examples.
- *Alternate*: Alternate scaling up and scaling down tiles.
- *Cumulate*: Scaling is cumulative.



Symmetry Shift **Scale** Rotation Blur & opacity Color Trace

Per row: Per column: Randomize:

Scale X: 0.0 % 0.0 % 0.0 %

Scale Y: 0.0 % 0.0 % 0.0 %

Exponent: 1.00 1.00

Base: 0.0 0.0

Alternate:

Cumulate:

Rows, columns: 2 x 2

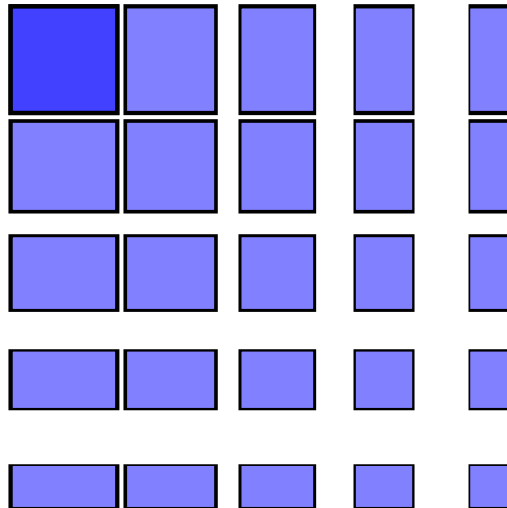
Width, height: 50.00 x 50.00 px

Use saved size and position of the tile

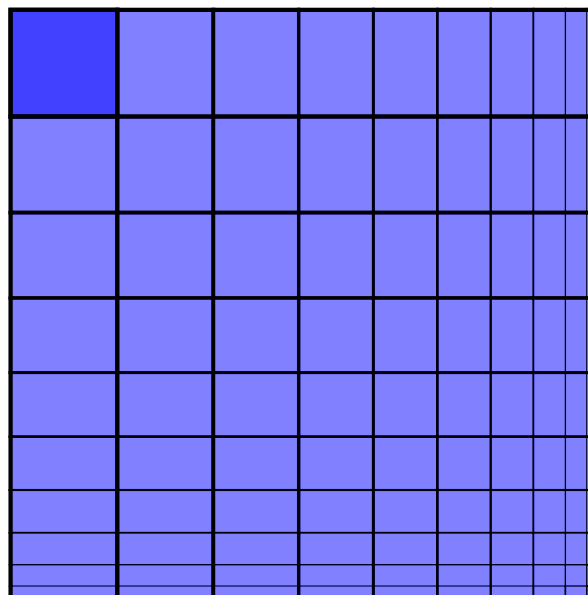
Reset Remove Unclump Create

Object has no tiled clones.

The *Scale* tab of the *Tile Clones* dialog.



A P1 symmetry tiling with a negative scaling. There is an -15% x scaling for each column and a -15% y scaling for each row. The scaling is a percentage of the base tile *bounding box*. The spacing between the center of adjacent tiles remains fixed.

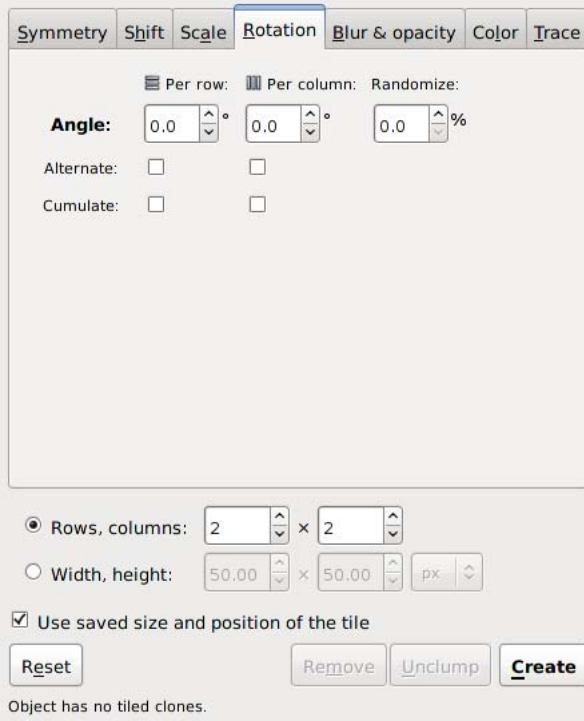


A P1 symmetry tiling with a cumulative negative scaling. There is a -10% x scaling for each column and a -10% y scaling for each row. There is also a -5% x shift for each column and a -5% y shift for each row. The *Cumulate* box is checked for both x and y . A general rule is that to keep scaled tiles just touching, specify a cumulative shift that is half of the scaling (in percent).

Rotation Tab

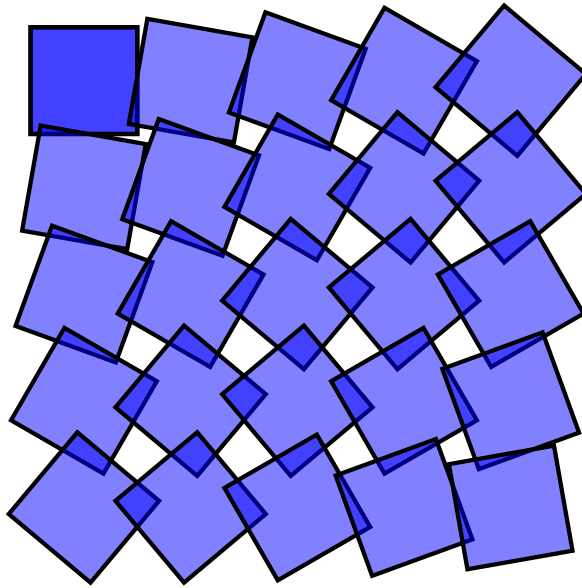
The *Rotation* tab allows one to rotate the tiles depending on the row and column position. As of v0.46, the *Rotation center* is used as the center of rotation. See the *Tile Tricks* section for examples of using a shifted *Rotation center*. The rotation is specified in degrees. The following options are available:

- *Angle*: Rotate by this amount around the *Rotation center*. A random factor can also be added.
- *Alternate*: The rotation alternates between being added and subtracted.
- *Cumulate*: Rotation is cumulative.

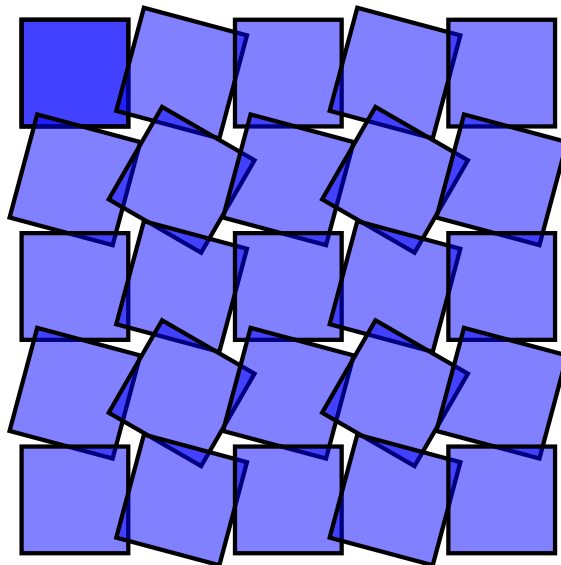


The screenshot shows the 'Rotation' tab of a software dialog. At the top, there are several tabs: 'Symmetry', 'Shift', 'Scale', 'Rotation' (which is selected), 'Blur & opacity', 'Color', and 'Trace'. Below the tabs, there are three columns of controls. The first column is labeled 'Per row:' and has a spin box for 'Angle' set to 0.0 with a degree symbol. The second column is labeled 'Per column:' and has a spin box for 'Angle' set to 0.0 with a degree symbol. The third column is labeled 'Randomize:' and has a spin box for a percentage set to 0.0 with a '%' symbol. Below these are two rows of checkboxes: 'Alternate:' and 'Cumulate:', each with two checkboxes. At the bottom of the dialog, there are radio buttons for 'Rows, columns:' (set to 2 x 2) and 'Width, height:' (set to 50.00 x 50.00 px). There is a checked checkbox for 'Use saved size and position of the tile'. At the very bottom, there are buttons for 'Reset', 'Remove', 'Unclump', and 'Create'. A status line at the bottom reads 'Object has no tiled clones.'

The *Rotation* tab of the *Tile Clones* dialog.



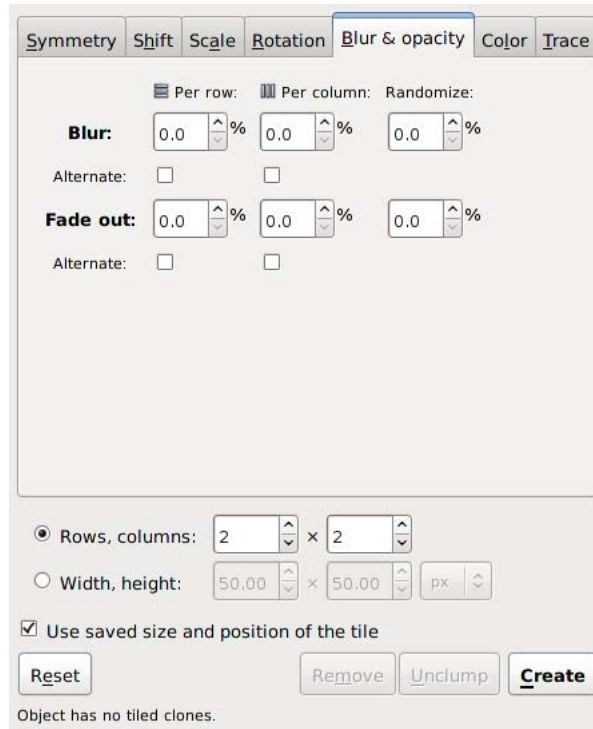
A P1 symmetry tiling with a 10° rotation for each row and column.



A P1 symmetry tiling with a 15° alternating rotation for each row and column.

Blur and Opacity Tab

The *Blur and opacity* tab allows one to change the *blur* and/or *transparency* of each tile depending on the row and column position.

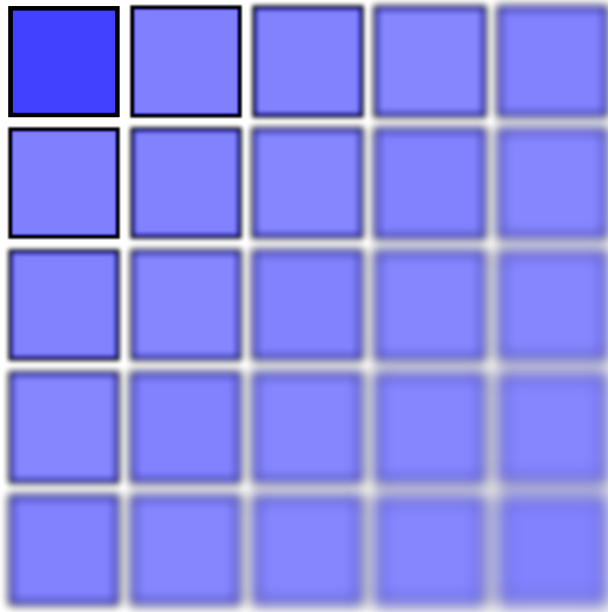


The *Blur and opacity* tab of the *Tile Clones* dialog.

Blur

A *Gaussian Blur* filter can be applied to each clone with different blurring values.

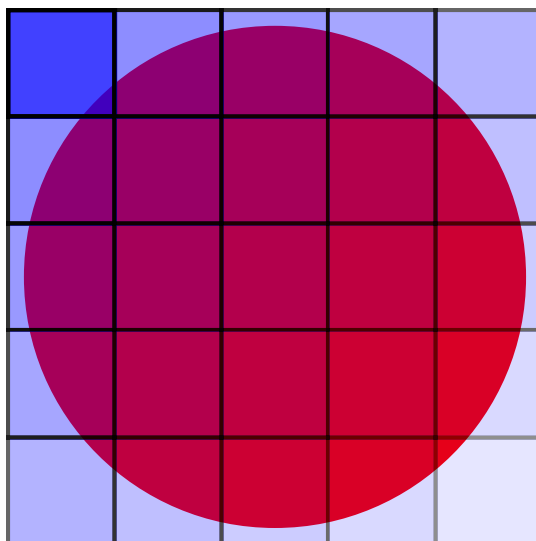
The blur change is specified in percent. The change in blur can be specified to *Alternate* between a positive and negative value; however, a negative blur value can be entered in the *Per row* and *Per column* boxes. A *Randomizer* factor can also be specified.



A P1 symmetry tiling with a 2% increase in blur for each row and column.

Opacity

The opacity change is specified in percent. The change in opacity can be specified to *Alternate* between a positive and negative value. A *Randomizer* factor can also be specified.



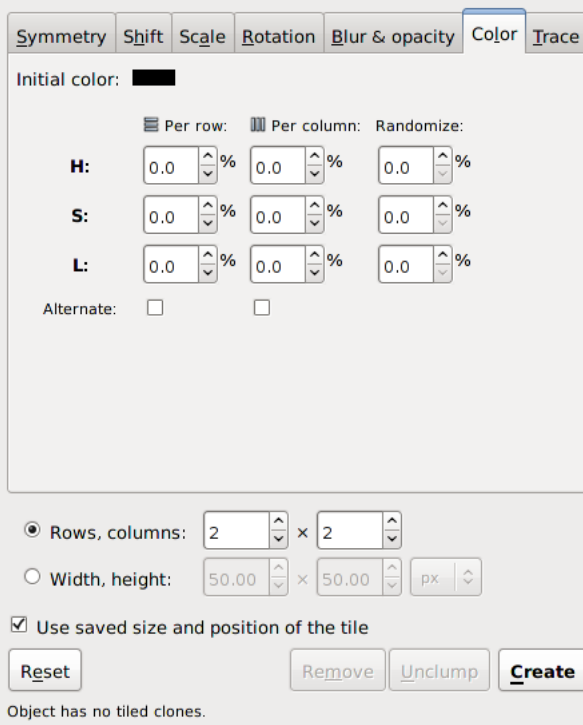
A P1 symmetry tiling with a 10% decrease in opacity for each row and column. A red circle has been placed under the tiling to illustrate the changes in opacity.

Color Tab

The *Color* tab allows one to change the *Color* of each tile depending on the row and column position. The color change is specified in percent for each of the three components of a color specified with the *HSL* standard (see the section called *HSL*). The *Hue* repeats itself after a change of 100%. The full scale for *Saturation* and *Lightness* components are each 100%. The changes in the three parameters can be specified to *Alternate* between a positive and negative change. A *Randomizer* factor can also be specified.

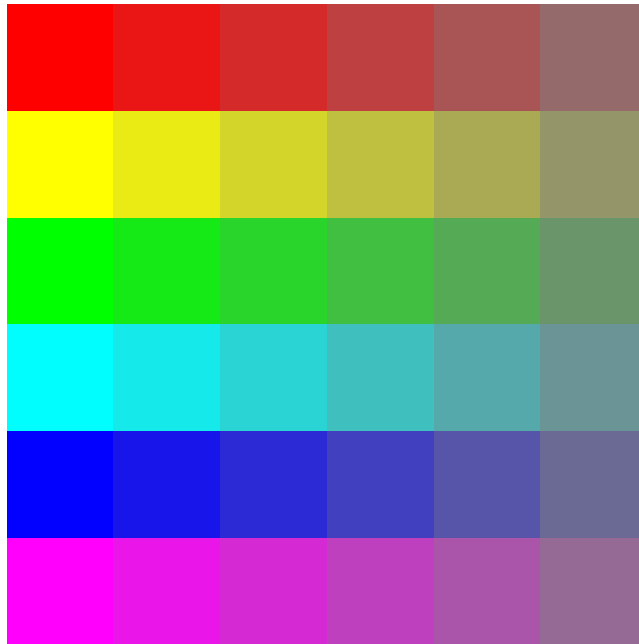
Two key points: First, the *Fill* and/or *Stroke paint* must be specified as *Unset (?)* (see the section called *Fill and Stroke Paint*). Second, an *Initial color* must be specified by using the *Initial color of tiled clones* dialog accessible by clicking on the color button next to the *Initial Color* label.

Note that it is meaningless to have only a shift in *Hue* with a starting color of black or white. This is like trying to walk east from the north pole.

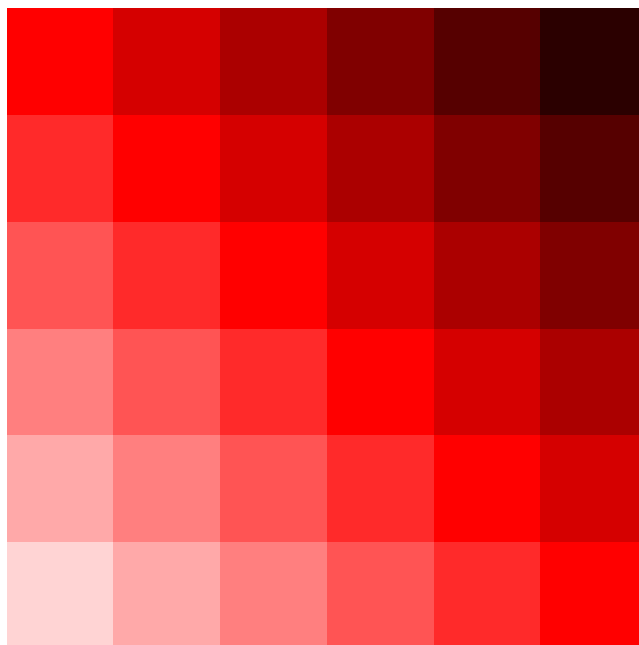


The screenshot shows the 'Color' tab of the 'Tile Clones' dialog. The 'Initial color' is set to black. The 'H', 'S', and 'L' components are each set to 0.0% for both 'Per row' and 'Per column' settings. The 'Randomize' checkbox is checked for each component. The 'Alternate' checkboxes are unchecked. The 'Rows, columns' option is selected with values of 2 rows and 2 columns. The 'Width, height' option is set to 50.00 x 50.00 px. The 'Use saved size and position of the tile' checkbox is checked. The 'Reset' button is visible, along with 'Remove', 'Unclump', and 'Create' buttons. A status message at the bottom indicates 'Object has no tiled clones.'

The *Color* tab of the *Tile Clones* dialog.



A P1 symmetry tiling with a 16.7% change in *Hue* per row and a -16.7% change in *Saturation* per column. The starting color is a red with 100% *Saturation* and 50% *Lightness*. ↻



A P1 symmetry tiling with an 8.3% change in *Lightness* per row and a -8.3% change in *Lightness* per column. The starting color is a red with 100% *Saturation* and 50% *Lightness*.

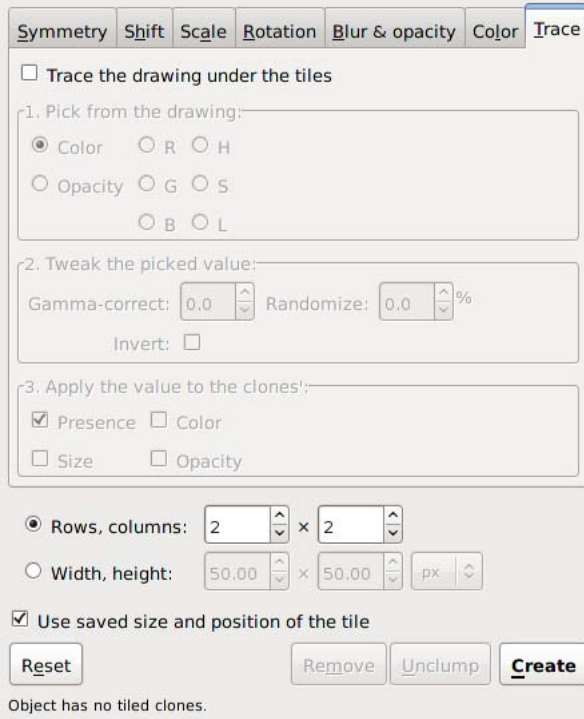
Trace

The *Trace* tab allows one to set the color, size, and transparency of the tiles by the color or transparency of the objects (including bitmaps) that are placed under the location of the tiling. To enable this feature, the *Trace the drawing under the tiles* box must be checked.

The *Trace* tab has three sections. At the top is a section for specifying what property of the underlying drawing should be used for input. Options include the color, one of the *RGB* components, or one of the *HSL* components. There is also the option to use the *Opacity*, which is the sum of the opacities (*Alpha*) of all objects under the tile.

In the middle of the tab is a section to modify the input value. One can specify a *Gamma*¹ correction or add a randomization factor to the input. One can also invert the input.

The bottom section is for specifying what should be affected by the input. Options include *Presence* (the probability that a given tile will be drawn), color, size, and opacity. The color will only be changed for regions of the base tile that have *Unset* fill.



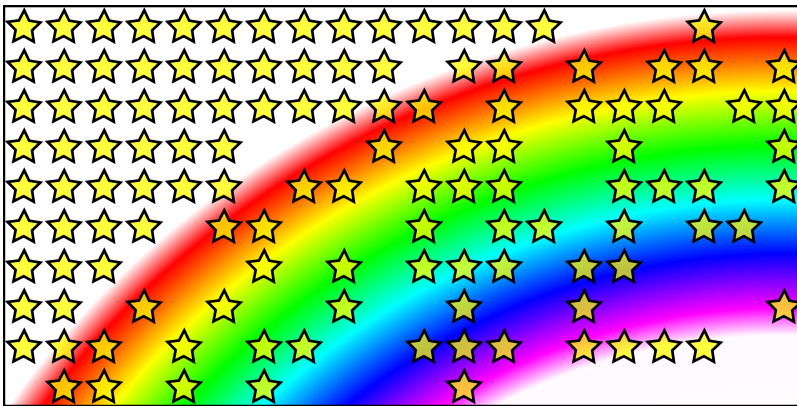
The *Trace* tab of the *Tile Clones* dialog.

The following figures show the effect of some of the possible combinations of input and output options. All the figures use the first rainbow figure as the input drawing. The rainbow is a *radial gradient* with multiple stops. The inside of the rainbow is defined as a white gradient stop with zero *Alpha*. The last outside stop is defined with a red color and with zero *Alpha*. For most figures, a star inside an unfilled rectangle is used as the base tile. The star has been given an *Unset* fill when color is selected in the output.

¹ See appendix for definition of *Gamma*.



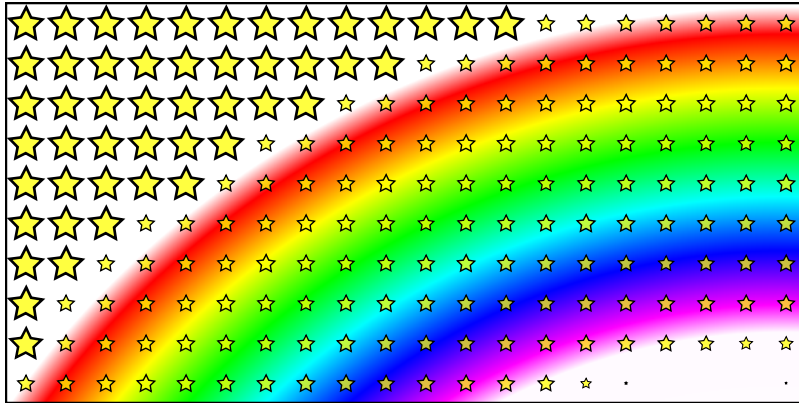
The rainbow pattern used for the background (a radial gradient).



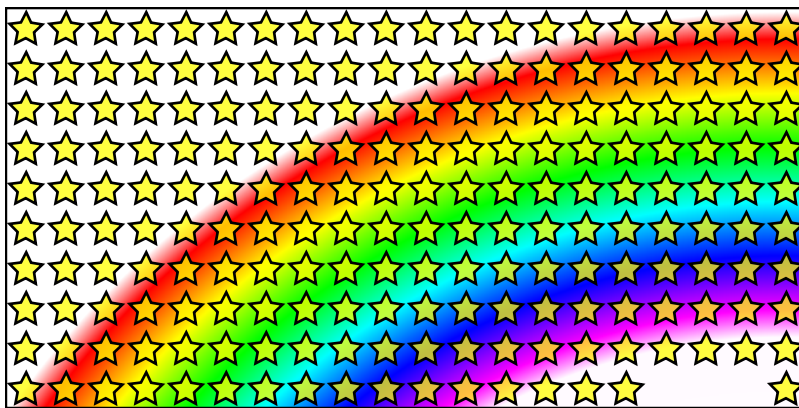
Input: Color. Output: Presence.



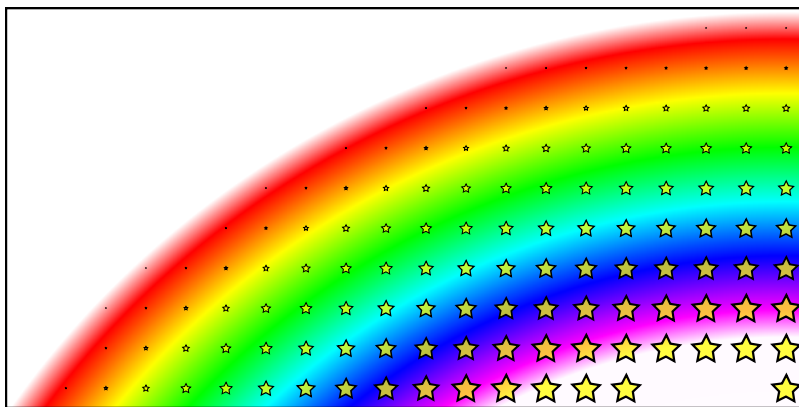
Input: Color. Output: Color. Background rainbow has been removed.



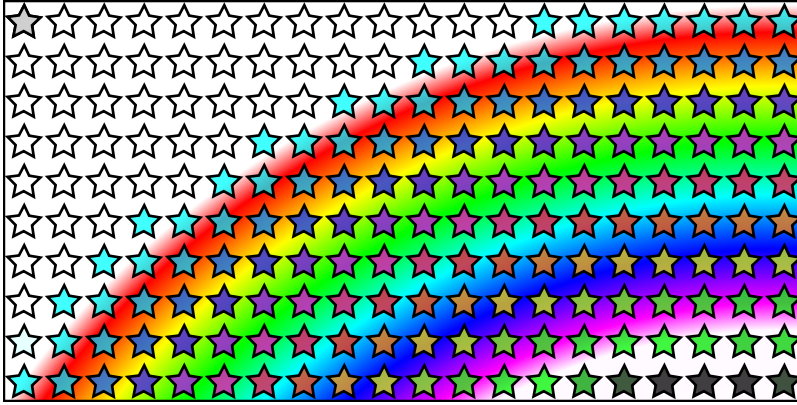
Input: Color. Output: Size.



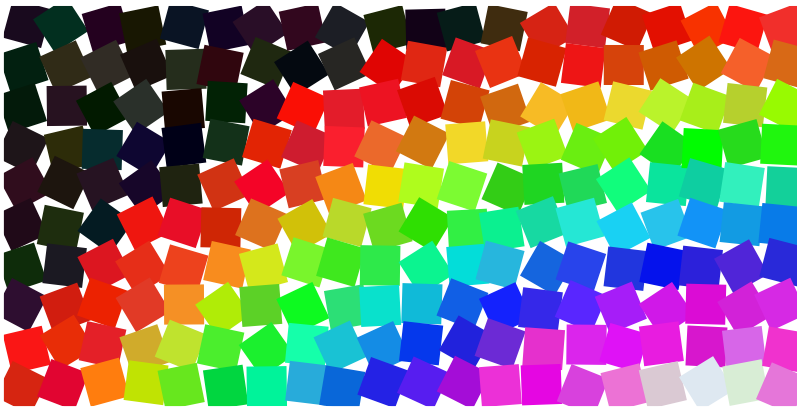
Input: Color. Output: Opacity.



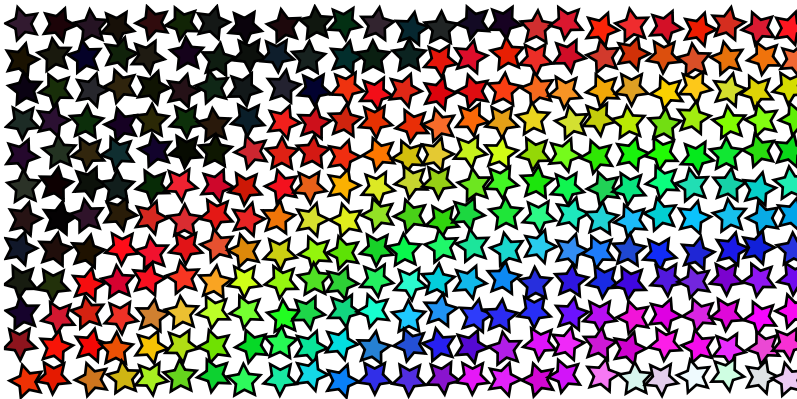
Input: Hue. Output: Size. Note how the red has a hue of zero and purple has the maximum value.



Input: Hue, inverted. Output: Color.



Input: Color, 10% random gamma. Output Color. Changes made to other tabs: Shift: random 10%, Rotation: random 20%. A square base tile with *Unset* fill has been used. The background rainbow has been deleted.

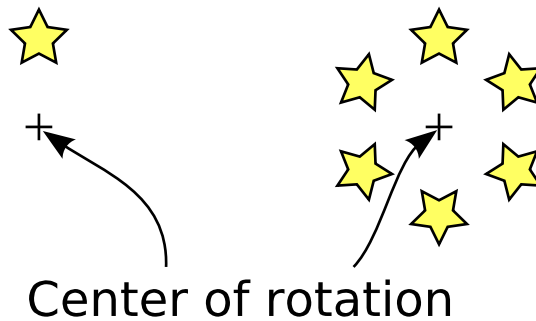


Input: Color, 10% random gamma. Output Color. Changes made to other tabs: Shift: -20%, random 10%, Rotation: random 20%. The number of rows and columns has been increased to compensate for the shift. The background rainbow has been deleted. 🌈

Tricks

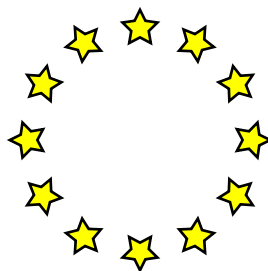
It is possible to exploit the *Tiling* dialog to produce a number of useful effects. The most interesting is placing tiles along an arc or spiral.

To put a tile along an arc use the P1 symmetry with one row of tiles. One use to have to resort to using a *Group* to put tiles along a curve. As of v0.46, the *Rotation center* is used as the center of rotation. One also used to have to specify a shift of -100% . Now one can just check the *Exclude tile* box.



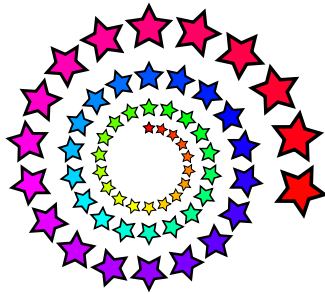
The base tile is drawn on the left, showing the *Rotation center* of the tile. On the right is after a P1 tiling with a per column shift removed by checking the *Exclude tile* box and with a rotation of 60% .

The next figure shows how 12 stars can be put in a circle. This would have been an alternative way of placing the stars in the European Union flag if the stars did not need to be placed with one of their points straight up.

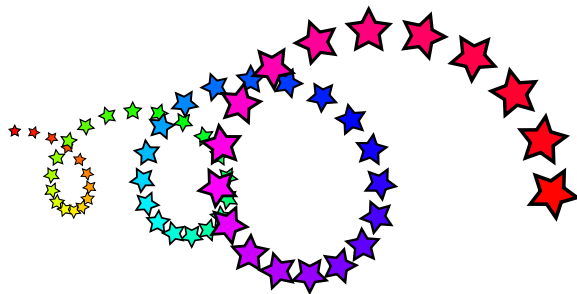


Twelve stars in a circle.

This trick can also place objects along a spiral by specifying that the tile should get larger with each column. As of v0.46, one can put the stars on a logarithmic spiral so that the stars don't run into each other after several loops.



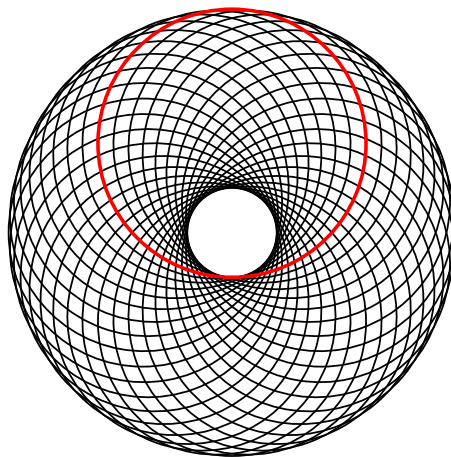
Stars on a logarithmic spiral. The tile size is increased by 2.5% with *Base* set to 2.7. Each tile is rotated 20°.



Stars on a logarithmic spiral. The tile size is increased by 2.5% with *Base* set to 2.7. Each tile is rotated 20°. The per column shift has been set to 60% (with the *Exclude tile* box checked).



A “P1 symmetry” tiling. 8 rows, 21 columns. Rotation of -11.5° per row and 20.6° per column, *Scale* of 39.3% per row and 24.2% per column with a *Base* of 2.7 for both x and y . The pattern matches that for a pine cone with 8 rows in one direction and 13 in the other. For the mathematicians: note that 13 times the per column scaling is equal to 8 times the per row scaling and that 13 times the per column rotation minus 8 times the per row rotation is equal to 360° . This is due to the constraint that the 14th star in the first row is the same as the 9th star in the first column.



A circle tiled on an arc. The red circle with the *Rotation center* moved off center was the source tile.

Index

Symbols

3D Box, 156
3D Polyhedrons Extension, 372

A

Add Node Extension, 361
Align, 150
Alphabet Soup Extension, 373
Alt Key, 405
Angle definition, 137
Animation, 66, 401
Arcs, 159
 Objects placed on, 326
Arrange Extension, 341
Attributes, 218
 Fill, 218
 Flat color, 219
 Gradients, 228
 Patterns, 235
 Fill rules, 238
 Stroke paint, 218
 Stroke style, 239
 Cap style, 241
 Complex, 243
 Dash style, 241
 Join style, 240
 Markers, 242
AutoCAD, 110
Autosave, 104

B

Bank Note, example, 82
Barcode Extension, 373
Batch Export, 108
Bezier Curve, 165
Bezier Tool, 168
Bitmap
 Copy, 130
Bitmaps, 341, 370
Blend, 280
Borders, 358
Bottle, 94
Bounding Box
 Alignment, 150
 Cap style, 241
 Distribution, 151
 Join style, 241
 Markers, 243
 Patterns, 236
 Tiles, 309

 Visual vs. Geometric, 137
Box-3D, 156
Brighter Color Extension, 342
Buttons, 362

C

Calendar Extension, 374
Calligraphy Tool, 171
Canvas, 2
 Panning, 122
 Zooming, 122
Cap style, 241
Cartesian Grid Extension, 374
Cascading Style Sheets, 398
Challenges, 413
 Knot, 413
 Pine cone, 414
 Red spiral, 413
 Spiral Gyral, 415
 Squares, 414
Change case text extensions, 388
Charts, 338
Circles, 159
Clip art, 107
Clipping, 252
 Bitmap, 238
Clones, 19, 130
 Find original, 131
 Tiling, 306
Color, 219
 CMS (Color Management System), 223
 CMYK (Cyan Magenta Yellow Key), 221
 Dropper Tool, 226
 Extensions, 342
 Gestures, 226
 HSL (Hue Saturation Lightness), 221
 Palette, 3, 223
 Profile, 219
 Randomize, 246, 348
 Replace, 350
 RGB (Red Green Blue), 220
 RGB Barrel, 350
 Style Indicator, 223
 Swatches dialog, 223
 Tweak Tool, 246
 Wheel, 222
Color Calibration, 3
Color Extension, 342
Color Markers to Match Stroke Extension, 362
Color Matrix, 277
Command Bar, 2
Command Line, 408
Complex Strokes, 243

- Component Transfer, 279
 - Composite, 282
 - Connectors, 338
 - Creating, 338
 - Modifying, 339
 - Routing, 339
 - Construct Grid LPE, 191
 - Convert to Braille Extension, 387
 - Convert to Dashes Extension, 362
 - Convolve Matrix, 289
 - Coordinates, 136
 - Copy, 129
 - Bitmap, 130
 - Drop, 130
 - Cropping
 - Bitmap, 238
 - Current style, 154
 - Custom Color Extension, 342
 - Customization, 404
 - Configuration files, 404
 - Custom keyboard shortcuts, 407
 - Custom markers, 406
 - Custom swatches (palettes), 406
 - Custom templates, 405
 - Inkscape Preferences dialog, 404
 - Outline Mode
 - At Start Up, 124
 - Colors, 124
 - SVG Output Format, 405
 - Custom keyboard shortcuts, 407
 - Custom templates, 405, 417
 - Cut, 129
- D**
- Darker Color Extension, 343
 - Dash style, 241
 - Defs
 - File format, 420
 - Vacuuming, 121
 - Delete, 130
 - Desaturate Color Extension, 344
 - Desktop Cutting Plotter, 110
 - Convert to Dashes Extension, 362
 - Dialogs
 - Align and Distribute, 150
 - Nodes, 182
 - Docking, 4
 - Document Preferences
 - Coordinates, 136
 - Grid, 8
 - Document Properties
 - Page size, 6
 - Export, 16, 107
 - Find, 128
 - Gradient Editor, 231
 - Guide line, 147
 - Hide, 123
 - Icon Preview, 124
 - Import, 22, 33, 104
 - Inkscape Preferences, 404
 - Pixel size, 137
 - Selection cues, 127
 - Simplify threshold, 186
 - Steps and Snap angles, 154
 - Transforms, 136
 - Object Properties, 127
 - Open (File), 103
 - Rows and Columns, 152
 - Swatches, 223
 - Text, 213
 - Tiling, 56, 306
 - Trace bitmap, 329
 - XML Editor, 68, 302
 - Dimensions Extension, 351
 - Displacement Map, 293
 - Distribute
 - Non-uniform, 152
 - Remove Overlaps, 152
 - Rows and Columns, 152
 - Uniform, 151
 - Dockable Dialogs, 4
 - Draw From Triangle Extension, 375
 - Draw Handles Extension, 389
 - Dropper Tool, 226
 - Drop Shadow, 274
 - Duplicate, 130
 - Window, 124
- E**
- ECMAScript, 401
 - Edge 3D Extension, 362
 - Effects (Extensions), 340
 - Ellipses, 45, 159
 - Tool Controls, 160
 - Embed All Images Extension, 361
 - Engraving, 175
 - Envelope Deformation LPE, 191
 - Envelope Extension, 363
 - Eraser Tool, 247
 - Cut-Out Mode, 247
 - Touch Mode, 247
 - Examples
 - Animation, 66
 - Bank Note, 82
 - Complex Strokes, 243
 - European Union Flag, 17

- Isometric Projection, 39
- Logo, 20
- Parallel lines, 176
- Scissors on path, 242
- Soup Can, 44
- Swedish Flag, 5
- Tile Pattern, 56
- Tracing, 32
- Export
 - Command Line, 409
 - Non-PNG Files, 109
 - PNG, 16, 107
- Export dialog, 107
- Extension
 - Arrange, 341
- Extensions, 340
 - 3D Polyhedrons, 372
 - Add Nodes, 361
 - Alphabet Soup, 373
 - Barcode, 373
 - Calendar, 374
 - Cartesian Grid, 374
 - Change Case, 388
 - Color, 342
 - Brighter, 342
 - Custom, 342
 - Darker, 343
 - Desaturate, 344
 - Grayscale, 344
 - Less Hue, 345
 - Less Light, 345
 - Less Saturation, 346
 - More Hue, 346
 - More Light, 347
 - More Saturation, 347
 - Negative, 348
 - Randomize, 348
 - Remove Blue, 349
 - Remove Green, 350
 - Remove Red, 349
 - Replace, 350
 - RGB Barrel, 350
 - Color Markers to Match Stroke, 362
 - Convert to Braille, 387
 - Convert to Dashes, 362
 - Dimensions, 351
 - Draw From Triangle, 375
 - Draw Handles, 389
 - Edge 3D, 362
 - Embed All Images, 361
 - Envelope, 363
 - Extract One Image, 361
 - Extrude, 351
 - Flatten Bezier, 363
 - Flip Case, 388
 - Foldable Box, 375
 - Fractal
 - Lindenmayer, 380
 - Fractalize, 364
 - Function Plotting, 376
 - Gear, 377
 - Grid, 378
 - Guides Creator, 378
 - Inside/Outside Halo, 352
 - Interpolate, 352
 - Interpolate Attribute in a Group, 364
 - Jitter Nodes, 365
 - LaTeX Formula, 379
 - Lorem Ipsum, 388
 - Lower Case, 388
 - L-system, 380
 - Measure Path, 389
 - Motion, 354
 - Number Nodes, 390
 - Parametric Curves, 380
 - Pattern Along Path, 355
 - Perspective, 366
 - Polar Grid, 382
 - Printing Marks, 383
 - Random Case, 388
 - Random Tree, 384
 - Raster, 370
 - Replace Text, 388
 - Rubber Stretch, 367
 - Scatter, 360
 - Sentence Case, 388
 - Set Attributes, 391
 - Spirograph, 384
 - Straighten Segments, 368
 - Text, 387
 - Title Case, 388
 - Transmit Attributes, 392
 - Triangle, 386
 - Upper Case, 388
 - Web, 391
 - Whirl, 369
- Extract One Image Extension, 361
- Extrude Extension, 351
- F**
 - File format, 417
 - Files, 103
 - Custom templates, 405
 - Export, 16, 107
 - Import, 104
 - New, 103
 - Open, 103

- Printing, 120
 - Revert, 103
 - Save, 103
 - Save a Copy, 103
 - Save As, 103, 109
 - Vacuuming Defs, 121
 - Fill, 218
 - Hatchings, 238
 - Spirals, 163
 - Filter Effects, 254, 272
 - Blend, 280
 - Color Matrix, 277
 - Component Transfer, 279
 - Composite, 282
 - Convolve Matrix, 289
 - Custom, 272
 - Displacement Map, 293
 - Example, 274
 - Flood, 283
 - Gaussian Blur, 295
 - Image, 283
 - Merge, 283
 - Morphology, 297
 - Offset, 297
 - Preset, 254
 - Tile, 284
 - Turbulence, 284
 - Filter Effects Region, 272
 - Filters, 254
 - Blend, 280
 - Color Matrix, 277
 - Component Transfer, 279
 - Composite, 282
 - Convolve Matrix, 289
 - Displacement Map, 293
 - Example, 274
 - Flood, 283
 - Gaussian Blur, 94, 295
 - Clipping and Masking, 296
 - Examples, 296
 - Fill and Stroke dialog, 295
 - Filter Effects dialog, 295
 - Gradients, 296
 - Gradient Blurring, 296
 - Image, 283
 - Merge, 283
 - Morphology, 297
 - Offset, 297
 - Tile, 284
 - Tile Clones Blurring, 296
 - Turbulence, 284
 - Find dialog, 128
 - Flags
 - European Union, 17
 - Swedish, 5
 - Flatten Bezier Extension, 363
 - Flip case text extension, 388
 - Flood, 283
 - Flourish, 359
 - Foldable Box Extension, 375
 - Fractal (Lindenmayer) Extension, 380
 - Fractalize Extension, 364
 - Fractals
 - Lindenmayer Extension, 380
 - VonKoch LPE, 204
 - Full Screen, 124
 - Function Plotting Extension, 376
- ## G
- Gaussian Blur, 295
 - Gear Extension, 377
 - Gears, 192, 377
 - Gestures
 - Color, 226
 - Stroke, 240
 - Gimp
 - Filtering, 329
 - Gradients, 47, 228
 - Blurring, 296
 - Editor dialog, 231
 - Reverse, 235
 - Gradient Tool, 233
 - Grayscale Color Extension, 344
 - Grid Extension, 378
 - Grids, 148
 - Groups, 132
 - Editing, 132
 - Guides, 17, 146
 - Guides Creator Extension, 378
- ## H
- Handles
 - Drawing, 389
 - Hatches (Rough) LPE, 192
 - Hatchings, 175, 202, 238, 246
 - Help, xvi
 - Hidden Object, 127
- ## I
- Icon Preview, 124
 - Illustrator, 110, 433
 - Image, 283
 - Import, 32, 104
 - Import dialog, 22, 33, 104
 - Inkscape Preferences dialog, 404
 - Inkview, 416
 - Inside/Outside Halo Extension, 352

Interpolate Attribute in a Group Extension, 364
 Interpolate Extension, 352
 Interpolate Sub-Paths LPE, 194
 Isometric Projection, 39, 158

J

JavaScript, 400, 401
 Set Attributes Extension, 391
 Transmit Attributes Extension, 392
 Jitter Nodes Extension, 365
 Join style, 240

K

Keyboard shortcuts
 Custom, 407
 Knot LPE, 194
 Koch's Snowflake, 380

L

LaTeX, 116
 Formula Extension, 379
 Presentation Styles, 118
 LaTeX Formula Extension, 379
 Layers, 133
 Less Hue Color Extension, 345
 Less Light Color Extension, 345
 Less Saturation Color Extension, 346
 Lindenmayer Extension, 380
 Linking (Web), 397
 Live Path Effects, 189
 Bend, 190
 Construct Grid, 191
 Envelope Deformation, 191
 Gears, 192
 Hatches (Rough), 192
 Interpolate Sub-Paths, 194
 Knot, 194
 Pattern Along Path, 195
 Ruler, 198
 Sketch, 198
 Spiro Spline, 200
 Stitch Sub-Paths, 201
 VonKoch, 204
 Locked Objects, 127
 Logo example, 20
 Lorem ipsum Extension, 388
 Lower case text extension, 388
 LPE, 189
 L-system Extension, 380

M

Markers, 242
 Color to Match Stroke, 362

 Custom, 242, 304, 406
 Masking, 252
 Measure Path Extension, 389
 Menu Bar, 2
 Merge, 283
 Money, 82
 More Hue Color Extension, 346
 More Light Color Extension, 347
 More Saturation Color Extension, 347
 Morphology, 297
 Motion Extension, 354

N

Negative Color Extension, 348
 Neon Sign, 66
 Nodes, 177
 Add Node Extension, 361
 Alignment, 182
 Auto-Smooth, 182
 Corner (Cusp), 166
 Editing
 Keyboard, 179
 Mouse, 178
 Inserting, 178, 180
 Sculpting, 183
 Selecting, 177
 Smooth, 165
 Tool Controls, 180
 Notification Region, 3, 11
 Objects selected, 127
 Nudge factor, 139, 177
 Number Nodes Extension, 390

O

Object Properties
 Desc, 400
 Hidden, 127
 JavaScript (ECMAScript), 400
 Locked, 127
 Title, 400
 Object Properties Dialog, 400
 Objects
 Hidden, 127
 Locked, 127
 Tweak Tool, 244
 Object to Path, 176
 Offset, 297
 Open Clip Art Library, 107
 Outline Mode, 124
 Colors, 124, 405

P

Page, 2

Paint Bucket Tool, 248
Palette, 3, 223
Panning, 122
Parallel lines, 176
Parametric Curves Extension, 380
Paste, 129
 In Place, 130
 Style, 130
Paste Size, 143
Paths, 165
 Bezier, 165
 Break apart, 186
 Combine, 185
 Creating, 166
 Editing, 177
 File format, 419
 Flatten Bezier Extension, 363
 Fractalize Extension, 364
 From other objects, 176
 Knot, 413
Live Path Effects, 189
 Bend, 190
 Construct Grid, 191
 Envelope Deformation, 191
 Gears, 192
 Hatches (Rough), 192
 Interpolate Sub-Paths, 194
 Knot, 194
 Pattern Along Path, 195
 Ruler, 198
 Sketch, 198
 Spiro Spline, 200
 Stitch Sub-Paths, 201
 VonKoch, 204
Merging, 13
Object to Path, 165
Offsets, 185
Operations, 186
 Cut Path, 187
 Difference, 29, 186
 Division, 187
 Exclusion, 187
 Intersection, 31, 187
 Union, 186
Reverse, 186
Simplify, 186
Tweak Tool, 245
Pattern Along Path, 195, 355
Patterns, 235
Pencil Tool, 166
Perspective, 179, 363, 366
Perspective Extension, 366
Photorealism, 94
Pine cone, 414

Plotter, 376
Polar Grid Extension, 382
Polygons, 160
Polyhedrons Extension, 372
PovRay, 115
Printing, 120
Printing Marks Extension, 383

Q

Quadrilateral Distortion Extension, 363

R

Random case text extension, 388
Randomize Color Extension, 348
Randomizer Extension, 365
Random Tree Extension, 384
Raster Extensions, 370
Rectangles, 11, 154
 Tool Controls, 155
Redo, 126
Remove Blue Color Extension, 349
Remove Green Color Extension, 350
Remove Overlaps, 152
Remove Red Color Extension, 349
Replace Color Extension, 350
Replace Text Extension, 388
Reverse Gradient, 235
Reverse Path, 186
Revert, 103, 126
RGB Barrel Color Extension, 350
Rotation Center, 139
Rows and Columns, 152
Rubber Stretch Extension, 367
Ruler LPE, 198
Rulers, 3, 136

S

Scatter, 360
Scripts, 340
Scroll Bars, 3
Security Markings, 82
Selection, 126
 Multiple objects, 127
 Tool, 126
 With Find dialog, 128
 With keyboard, 128
 With mouse, 127
Sentence case text extension, 388
Set Attributes Extension, 391
Shadows, 49, 352
Shapes, 154
SIOX (Simple Interactive Object Extraction), 337
Sketch LPE, 198

- Slices, 109
 - Snap Angles, 154
 - Snap Bar, 2
 - Snapping, 144
 - Guides, 146
 - Soup Can, 44
 - Spheres, 421
 - Spiral Gyral, 415
 - Spirals, 162
 - Objects placed on, 326
 - Tool Controls, 163
 - With gradient, 413
 - Spirograph Extension, 384
 - Spiro Spline LPE, 200
 - Squares, 154
 - Stars, 18, 160
 - Tool Controls, 162
 - Status Bar, 3
 - Steps, 154
 - Stitch Sub-Paths, 201
 - Straighten Segment Extension, 368
 - Stroke
 - Gestures, 240
 - Stroke paint, 218
 - Stroke style, 239
 - Stroke to Path, 176
 - Style Indicator, 3, 223
 - Style Sheets, 398
 - SVG
 - File format, 417
 - Output Format, 405
 - Symmetries, 307
- T**
- Tablet Input, 173
 - Templates
 - Custom, 405
 - Default, 103, 417
 - Tessellation, 306
 - TeX, 116, 118
 - Text, 208
 - Baseline, 209
 - Change Case, 388
 - Create, 21
 - Creating, 208
 - Editing, 210
 - Flowed Text object, 209
 - Font, 213
 - In a shape, 216
 - Justification, 214
 - Kerning, 214
 - Linked flowed text, 216
 - On path, 215, 359
 - Regular Text object, 209
 - Rotating
 - Individual characters, 214
 - Selecting, 209
 - Spell Checking, 210
 - Style, 211, 213
 - Text to path, 23, 209
 - Underlined, 304
 - Unicode, 208
 - Text Dialog, 213
 - Text Extensions, 387
 - Tile, 284
 - Tile Pattern, 56
 - Tiling, 306
 - Base tile, 309
 - Blur, 318
 - Blurring, 296
 - Color, 320
 - Opacity, 319
 - Rotating, 316
 - Scaling, 314
 - Shifting, 310
 - Symmetries, 307
 - Tracing, 322
 - Tricks, 326
 - Tiling dialog, 56, 306
 - Title case text extension, 388
 - Tool Box, 2
 - Tool Controls, 2
 - Box, 157
 - Ellipse, 160
 - Node, 180
 - Rectangle, 155
 - Spiral, 163
 - Star, 162
 - Tools
 - Bezier, 168
 - Box, 156
 - Calligraphy, 171
 - Hatchings, 175
 - Tablet, 173
 - Dropper, 226
 - Ellipse, 159
 - Eraser, 247
 - Gradient, 233
 - Node, 177
 - Paint Bucket, 248
 - Pencil, 166
 - Rectangle, 154
 - Selection, 126
 - Spiral, 162
 - Star, 18, 160
 - Tweak, 244
 - Zoom, 123

- Tool tips, 11
- Trace bitmap dialog, 329
- Tracing, 94
 - Bitmaps, 329
 - SIOX, 337
 - Tiles, 322
- Tracing example, 32
- Transformations, 137
- Transforming, Rectangles, 136
- Transmit Attributes Extension, 392
- Triangle Extension, 386
- Turbulence, 284
- Tweak Tool, 244
 - Colors, 246
 - Objects, 244
 - Paths, 245

U

- Undo, 126
- Upper case text extension, 388

V

- Vacuuming Defs, 121
- VonKoch LPE, 204

W

- Wacom Tablet, 173
- Web, 394
 - Animation, 401
 - Extensions, 391
 - JavaScript, 400
 - Linking, 397
 - Object Tag, 394
 - Style Sheets, 398
- Web Extension, 391
- Whirl Extension, 369
- Window
 - Duplicate, 124
 - Main, 1
- Wire Frame, 124

X

- XHTML, 394
- XML Editor, 302
 - Examples, 304
 - Color markers, 304
 - Underlined text, 304

Z

- Zooming, 122
- Zoom Tool, 123
- Z-order, 131