florilegium

Procedurally generated page margins for LuaLaTeX,
and plants, their visitors, shells and Gothic tracery in TikZ

Version 2.1.0, 17 November 2026

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https://github.com/kevinraymond/florilegium



Contents

1 Introduction **5**

1.1 Origin . . . 5

1.2 Quick start . . . 5

2 Using the package **6**

2.1 A first document . . . 6

2.2 Options . . . 6

2.3 Commands . . . 7

2.4 Seeds . . . 8

2.5 Colors . . . 8

2.6 The margin reads the text . . . 9

2.7 Less in the margin . . . 10

2.8 Pages without a margin . . . 10

2.9 Both sides of the page . . . 11

2.10 One ornament in the text . . . 12

2.11 A tagged PDF . . . 12

2.12 Primitives in a TikZ picture . . . 13

3 The TikZ library **13**

3.1 Files . . . 14

3.2 Pics . . . 14

3.3 A genome of your own . . . 16

3.4 Engines . . . 17

3.5 pdfLaTeX's memory . . . 17

3.6 What is TikZ, and what is not . . . 18

3.7 A change to pgf at load time . . . 18

4 The species garden **18**

4.1 A genome . . . 19

4.2 In words . . . 20

4.3 A genome of your own . . . 21

4.4 A document's plants . . . 21

4.5 Visitors . . . 22
4.6 Seasons and headings . . . 23
4.7 Drawn in v1.3's hand . . . 23
4.8 One seed, one species, in Lua or TikZ . . . 24
4.9 Sources . . . 24

5 Traits **25**
5.1 A species . . . 25
5.2 A visitor . . . 27
5.3 A window of tracery . . . 28
5.4 A shell . . . 29

6 Gothic tracery **30**
6.1 A window's genome . . . 30
6.2 On the page . . . 32
6.3 The initial's arch, and ornaments . . . 32
6.4 In TikZ . . . 32
6.5 How it is drawn . . . 33
6.6 Sources . . . 33

7 Shells **34**
7.1 A shell's genome . . . 34
7.2 On the page . . . 35
7.3 In TikZ . . . 35
7.4 How it is drawn . . . 36
7.5 Sources . . . 36

8 Themes **37**
8.1 Geometric . . . 37
8.2 Math . . . 38
8.3 Shells . . . 39
8.4 Writing a theme . . . 40

9 How it works **41**

9.1 Painting . . . 41

9.2 The grown margin . . . 42

9.3 Reading the page . . . 44

9.4 The authored page . . . 44

9.5 Initials . . . 44

9.6 Watching it grow . . . 44

9.7 Procedural is not random . . . 44

9.8 Size and time . . . 45

10 SVG, Typst and the browser **45**

10.1 A page as SVG, without TeX . . . 45

10.2 In Typst . . . 46

10.3 The playground . . . 46

11 Building and checking **47**

11.1 Checks . . . 47

12 Credits and license **48**

12.1 Credits . . . 48

12.2 License . . . 49

1 Introduction



rocedurally generated Delft-blue page margins for LaTeX, their plants, visitors, shells and Gothic tracery sampled from genomes. No images, no imported paths, no external assets: every petal, leaf, stem, whorl and arch is a curve computed while the page is being written, painted like a watercolor, and written straight into the PDF. Every page grows a garden of its own, and each document's seed its own plants.

1.1 Origin

The Reddit post asked how to make flowers like these in LaTeX. I don't know how the original was made. This project is one possible way. The way I did it first, in 1.3, uses hand-authored primitives with randomized parameters, painted in Lua and placed by a procedural layout whose "fill the unused space" part borrows a 1998 idea from the ornament literature. In 2.0 the plants and animals of the grown margin are sampled from genomes of botanical traits, so what grows is procedural too, not only where it grows. It gets a similar look, but I explicitly tried to not replicate the original.

This project was made with the assistance of AI (Claude), and I'm sharing the process I used to bring it to life.

1.2 Quick start

With LuaLaTeX, put `florilegium.sty` and the `florilegium*.lua` files beside your document (or upload them to an Overleaf project set to LuaLaTeX). They are all in `florilegium.zip`, with the TikZ library and the manual:

```
\usepackage[a4paper,left=68mm,right=22mm]{geometry}   % a wide margin for the garden
\usepackage[grown,sections]{florilegium}              % flowers at the headings, too
\definecolor{ink}{HTML}{5B2A1F}                       % optional: any hue (this is
↪  sepia)
...
\florilegiuminitial[4]{T}his paragraph starts with a decorated T.
\florilegiumtextend                                   % at the very end: fill the space
↪  below
```

With pdfLaTeX, or in any TikZ picture, the TikZ library draws the same species in pure TikZ (it needs only its two `tikzlibraryflorilegium*.code.tex` files):

```
\usepackage{tikz}
\usetikzlibrary{florilegium}
\begin{tikzpicture}
  \pic {florilegium plants={plants={3/rose, 17/umbellifer, 29/mustard}, size=21cm,
  ↪  width=6cm}};
\end{tikzpicture}
```

Under pdfLaTeX a strip this tall needs more memory than pdfTeX has by default; run it as `extra_mem_top=10000000 pdflatex doc.tex` (pdfLaTeX's memory).

Using the package lists every option and command.

2 Using the package

`florilegium.sty` needs LuaLaTeX and one run (two for the seasons). Put it and the `florilegium*.lua` files beside your document, or install them all in one folder of your TeX tree (for example `~/texmf/tex/latex/florilegium/`), where LuaLaTeX finds the Lua files too. On Overleaf, upload them to the project and set the compiler to LuaLaTeX.

For plants and visitors in a TikZ picture, under pdfLaTeX as well, see the TikZ library; it needs neither the package nor Lua.

2.1 A first document

```
\documentclass{article}
\usepackage[a4paper,left=68mm,right=22mm]{geometry}   % a wide left margin for the
↪  garden
\usepackage[grown,sections]{florilegium}
\begin{document}
\section{Spring}
\florilegiuminitial[4]{T}his paragraph starts with a decorated T, and the margin beside
↪  it
grows a garden of its own.
\florilegiumtextend
\end{document}
```

`grown` grows the margin to fit each page, from plants sampled for the document (see the species garden). Plain `\usepackage{florilegium}` draws the *authored* page instead, a composition placed by hand and tuned for A4 with a 68 mm left margin, in v1.3's hand-designed shapes.

2.2 Options

option	what it does
`grown`	the garden grown to fit the page; without it, the authored composition
`sections`	a flower beside every numbered section and subsection, in the copper of the accents (standard classes and KOMA-Script's; grown only)
`aging`	the garden ages from spring on the first page to autumn on the last (grown only; two runs, for the page count)
`novisitors`	no butterflies, bees, beetles, dragonflies, caterpillars, snails or birds
`noshells`	no shells on the margin's ground (see shells)
`theme=geometric`, `theme=math`, `theme=shells`	another drawing, or another composition (see themes)
`density=0.4`	less in the margin, down to a single vine at `0.05` (grown only)
`intensity=0.6`	a paler margin, from `1` as painted to `0.3` faint

option	what it does
`headpieces`	a headpiece of Gothic tracery over every `\section`, a vine up its jamb from the margin (standard classes; see tracery)
`nomargin`	no garden in the margin; ornaments, initials and `\florilegiumdraw` still work (for single pages, see Pages without a margin)

2.3 Commands

command	what it does
`\florilegiumtextend`	at the very end of the text, so that the garden also fills the space below it, in the same run
`\florilegiuminitial[5]{E}`	at the start of a paragraph, the letter as a decorated initial in a tile five lines tall (default 4)
`\florilegiuminitialfont{file.otf}`	the OpenType font the initial's outline is read from (default Latin Modern Bold)
`\florilegiuminitialframe{arch}`	the initials from here on open as a cusped arch of tracery, with stone round it (`plain` for the square)
`\florilegiumheadpiece`, `\florilegiumheadpiece[seed=7, width=10cm, vine=none]`	a headpiece of Gothic tracery across the line, its sill on the baseline; with the margin on, a vine up the jamb on the margin's side and a branch to it (see tracery)
`\florilegiumbloom`, `\florilegiumbloom[lily]`	a flower in the margin beside this line, or a bud, a leaf, a tendril, a role or a body plan on the page (grown only)
`\florilegiumage{0.8}`	the age of the pages from here on, from 0 (spring) through 0.5 (summer) to 1 (autumn) (grown only)
`\florilegiumtheme{geometric}`	another theme from the page this stands on (`flora` for none)
`\florilegiumoff`, `\florilegiumon`	no margin from the page this stands on, and the margin again
`\florilegiumhide`, `\florilegiumhide[1,3,5-8]`	no margin on the page this stands on, or on those pages of the PDF
`\florilegiumornament{leaf}`	one primitive in the line, the size of a letter
`\florilegiumdraw{flower}{1.2}`	one primitive at the origin of the current TikZ scope
`\florilegiumframe[explain]{k}{n}`	frame k of n of the garden's growth, for an animation (`animation.tex`)

2.4 Seeds

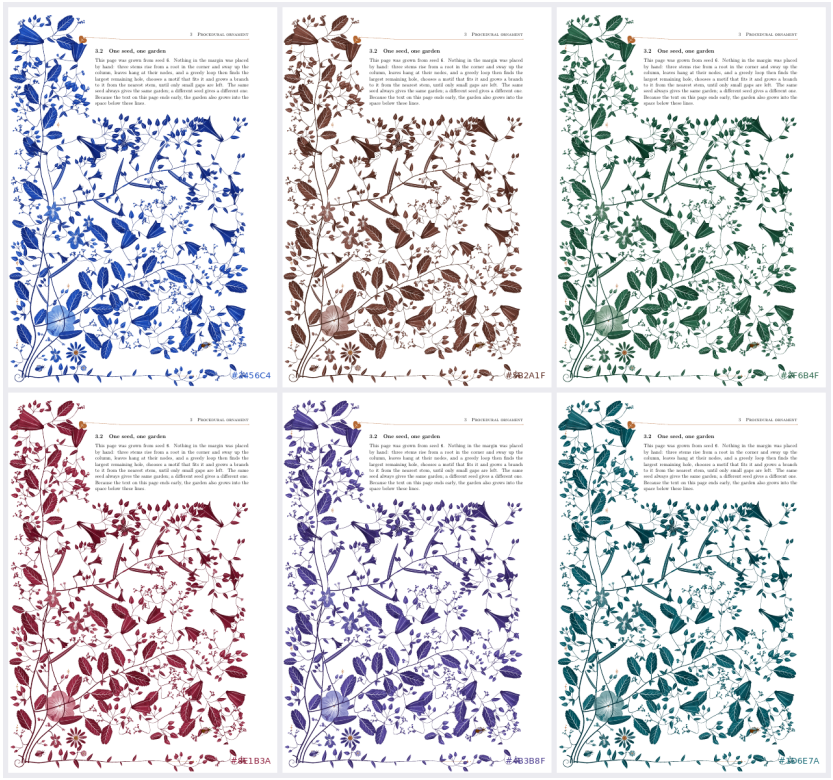
A page's garden comes from its page number, so page n gets the same garden on every build. `\def\florilegiumseed{7}` before `\usepackage` picks another set for the whole document, and the eight species its pages share. From the command line:

```
lualatex "\def\florilegiumseed{7}\input{florilegium-grow.tex}"
```

2.5 Colors

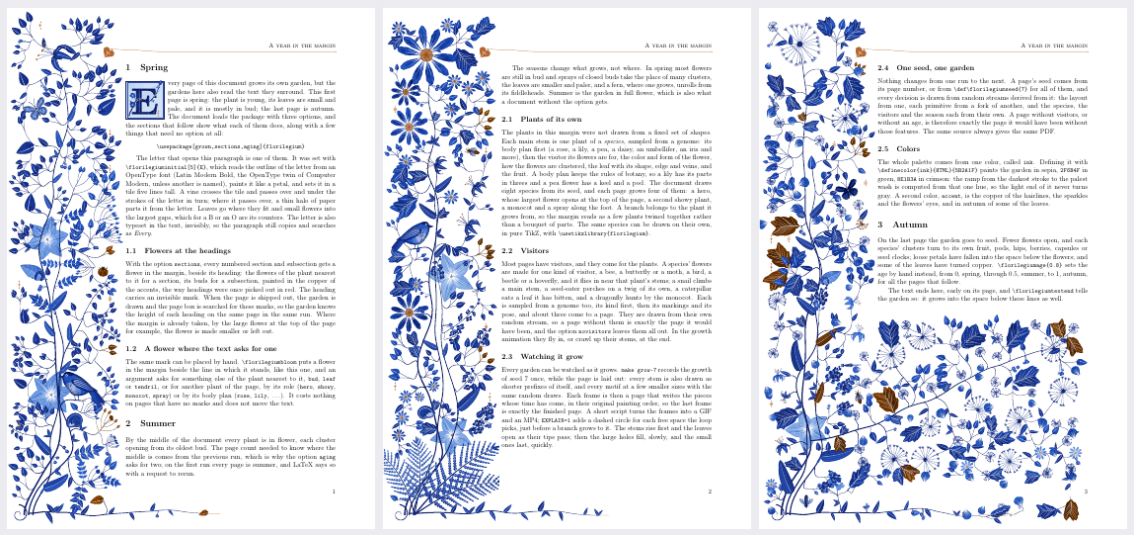
The whole palette comes from one color, `ink`, and the hairlines and copper accents from a second, `accent`. Define either after loading the package.

```
\definecolor{ink}{HTML}{5B2A1F}      % sepia instead of Delft blue
\definecolor{accent}{HTML}{B4662F}   % the copper
```



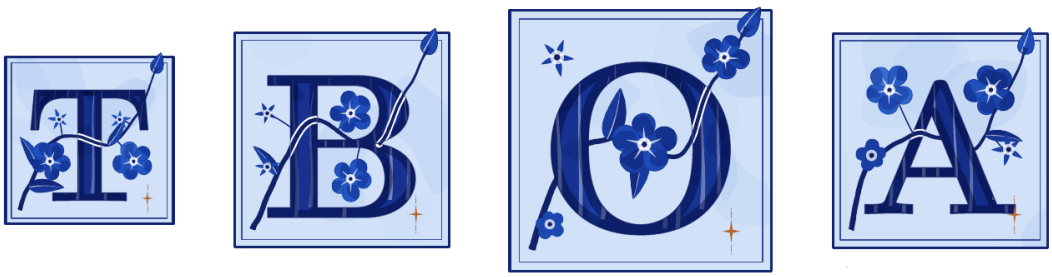
One seed in six inks: Delft blue, sepia, green, crimson, violet, teal. The ramp from the darkest stroke to the palest wash is computed from that hue in OKLCH, so the light end never turns gray.

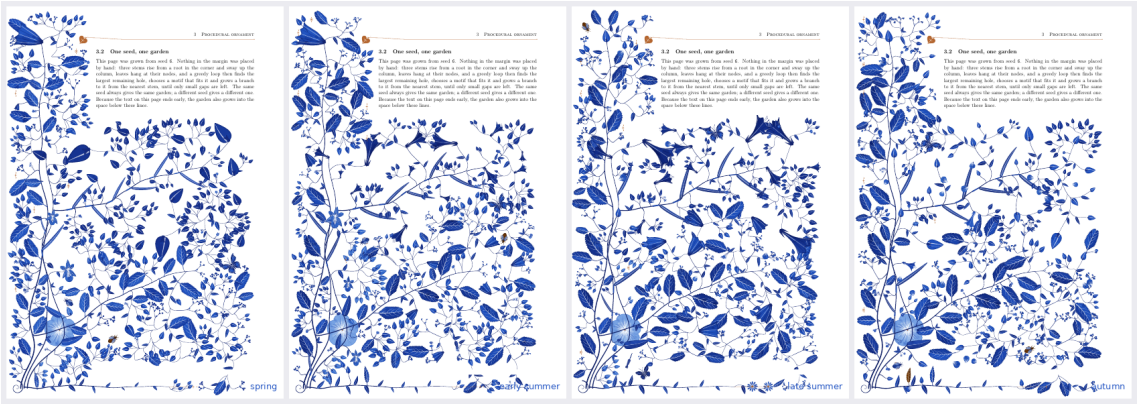
2.6 The margin reads the text



showcase.tex, "A year in the margin": spring on the first page, summer, autumn on the last. Each section describes the feature it shows.

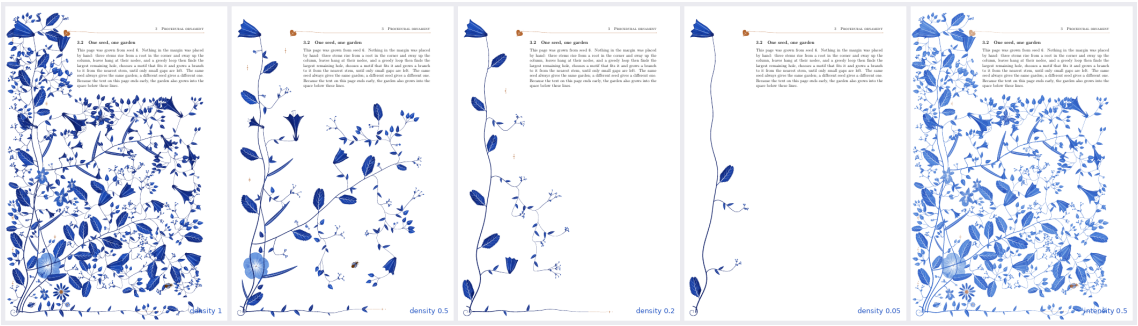
- **Initials.** The outline of the letter is read from an OpenType font and painted like a petal. A vine passes over and under its strokes in turn, with leaves where they fit and flowers in the gaps, often in the letter's counters. The letter is also typeset invisibly, so the paragraph still copies as "Every".
- **Flowers at the headings.** With `sections`, every numbered section and subsection gets a flower beside it in the copper of the accents, the way headings were once picked out in red.
- **A flower where the text asks.** `\florilegiumbloom` leaves a mark in the text. The marks are found in the page box when the page is shipped out, so this works in one run. A name that is no motif, role or plan on the page (a typo, `lilly`) draws nothing and says so in the log.
- **Seasons.** With `aging`, the garden ages from spring on the first page (buds, small pale leaves, fiddleheads) to autumn on the last (fruit and seed heads, falling petals, a few copper leaves). It needs two runs, for the page count; `\florilegiumage{0.8}` sets an age by hand.





One seed in spring, early summer, late summer and autumn. The seasons change what grows, not where.

2.7 Less in the margin



Seed 6 at `density=1`, `0.5`, `0.2` *and* `0.05`, *and at* `intensity=0.5`.

A full garden is a lot to have beside an equation. `density=0.4` grows less: the loop stops at larger holes, keeps more paper around each motif, and hangs fewer leaves and fillers. Low on the dial the plant itself thins out, to two main stems, then one, then no footer; at `0.05` it is a single vine with its flower, a couple of leaves and one or two sprays. With the math theme it means fewer things. `intensity=0.5` paints the whole margin paler, the way the ghost flowers behind the garden are painted; it changes only the color, not the detail. At `1` and `1` every page is the page it would have been without them.

2.8 Pages without a margin

A title page or a page of figures may want no garden. `\florilegiumoff` stops the margin with the page it stands on, and `\florilegiumon` starts it again. In the preamble they apply from the first page.

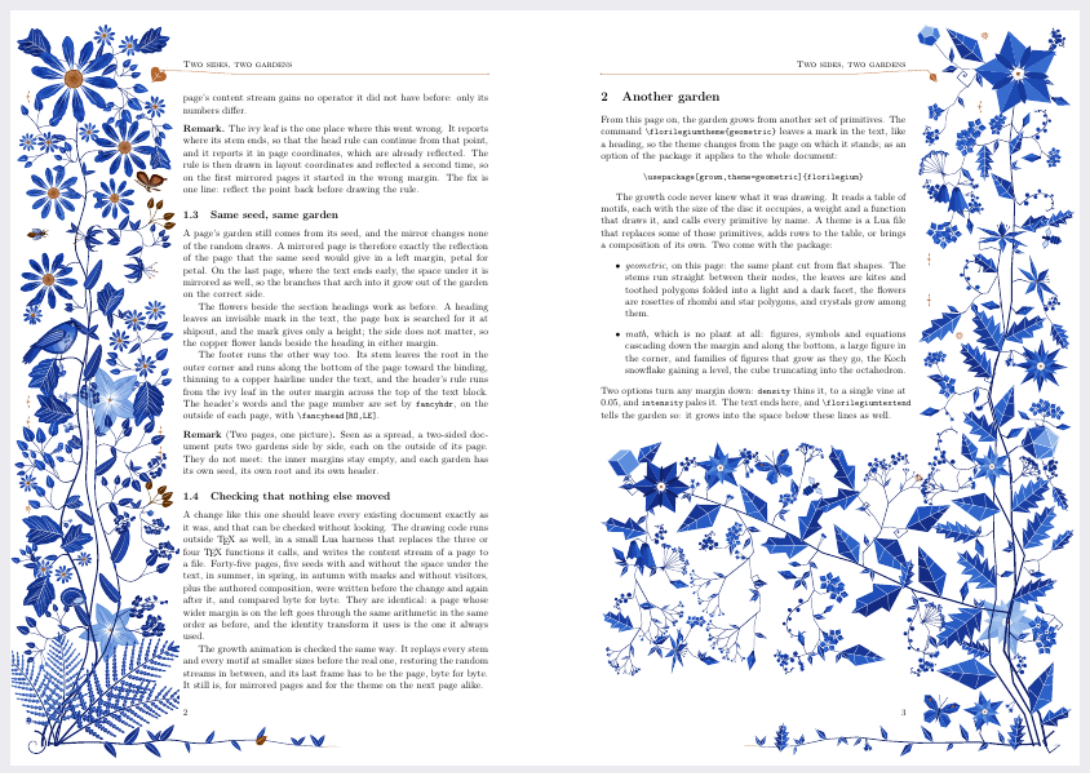
```
\begin{document}
\florilegiumoff
\begin{titlepage} ... \end{titlepage}
\florilegiumon                  % after the page break, so the title page stays bare
\section{Introduction}
```

Both take effect on the page where they end up, as `\florilegiumtheme` does, so `\florilegiumon` goes after the `\newpage` or `\clearpage` that ends the last bare page. When a page holds several of them, the last one decides.

`\florilegiumhide` leaves out only the page it stands on. Inside a `figure` or a `table` that is the page the float lands on, wherever LaTeX puts it. `\florilegiumhide[1,3,5-8]` leaves out pages by number, anywhere before they are reached. The numbers count the pages of the PDF from 1, as a PDF viewer does, whatever the document prints at the foot, so roman front matter or a title page that starts the numbering again cannot be mistaken for another page.

A page without its margin changes nothing else. Its text is set the same, its initials, ornaments and headpieces are still drawn (a headpiece without its vine, since no branch can reach it), every other page keeps the garden it would have had, and with `aging` it still counts as a page of the year. The option `nomargin` leaves the margin out of the whole document, and `\florilegiumon` cannot bring it back.

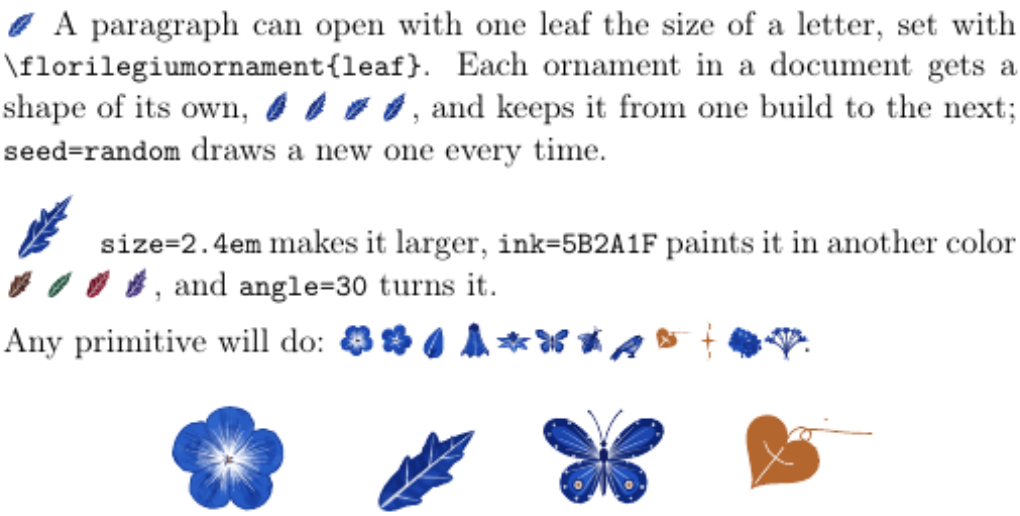
2.9 Both sides of the page



`spread.tex`, pages 2 and 3: a two-sided document with a wide outer margin. The last page also switches to the geometric theme.

The garden grows in whichever side margin is wider, so there is nothing to set. In a two-sided document (`twoside` with a wide outer margin) it changes sides with the page, and a one-sided document with a wide right margin gets it on the right of every page. A mirrored page is laid out as if seen in a mirror, then drawn through a reflection, the last transform every point passes through, so it is exactly the reflection of the garden the same seed would grow on the left.

2.10 One ornament in the text



`\florilegiumornament{leaf}` sets one primitive in the line, in a box the size of a letter, for example to open a paragraph. Each ornament in a document gets a shape of its own and keeps it from one build to the next; `seed=random` draws a new one every time the PDF is built, and `seed=7` a fixed one.

```
\usepackage[nomargin]{florilegium}       % ornaments only, no garden in the margin
\florilegiumornament{leaf} A paragraph that opens with a leaf.
\florilegiumornament[size=2.4em, ink=5B2A1F, angle=30, seed=random]{flower}
```

Any of v1.3's primitives works (`leaf`, `leaflet`, `flower`, `blossom`, `bud`, `bell`, `lily`, `cyme`, `umbel`, `butterfly`, `bee`, `bird`, `hedera`, `sparkle`, ...), and so do the current theme's (`crystal` with `geometric`; `knot`, `polyhedron`, `koch`, ... with `math`), the tracery's (`trefoil`, `quatrefoil`, `cinquefoil`, `sexfoil`, `rose`) and the shells' (`scallop`, `ammonite`, `nautilus`, `whelk`, `cowrie`).

2.11 A tagged PDF

LaTeX can tag a PDF (`\DocumentMetadata{tagging=on}`), so that a screen reader knows what each part of the page is. Accessibility standards such as PDF/UA ask for it. In a tagged PDF the package marks what it draws as decoration, which a reader passes over: the margin, the initials' tiles and the headpieces. An initial's letter still reads in its word, "This" and not "his".

An ornament in the text is decoration too, unless it says something. Give it `alt` and it becomes a figure with that description; give it `actualtext` and it is read and copied as that text, for example a section break that stands for `*`. With both, `alt` is used.

```
\DocumentMetadata{lang=en-US, tagging=on}
...
\florilegiumornament[alt={an ivy leaf}]{leaf}
\florilegiumornament[actualtext={*}]{sparkle}
```

`\florilegiumdraw` and the TikZ library's pics draw inside a TikZ picture, so LaTeX tags them as it tags any TikZ picture. Tagging was checked with TeX Live 2026. TeX Live 2023's tagging is an early test, and there the package marks nothing.

2.12 Primitives in a TikZ picture

`\florilegiumdraw` draws one of v1.3's primitives inside a TikZ picture, under the current scope's shift, rotation and scale. It is Lua, so it needs LuaLaTeX; for the species, use the TikZ library's pics.

```
\begin{tikzpicture}
  \begin{scope}[shift={(2,2)},rotate=20]\florilegiumdraw{flower}{1.3}\end{scope}
  \begin{scope}[shift={(5,0)}]\florilegiumdraw{leaf}{3.0, {depth=0.6}}\end{scope}
  \begin{scope}[shift={(8,1)}]\florilegiumdraw{ghost}{"lily", {s=1.4}}\end{scope}
  \begin{scope}[shift={(11,1)}]\florilegiumdraw{butterfly}{1.5}\end{scope}
\end{tikzpicture}
```

With a theme, its primitives can be drawn by name too: `\florilegiumdraw{crystal}{1.0}` under `theme=geometric` (see `specimen-geometric.tex`), `\florilegiumdraw{knot}{1.2}` under `theme=math`.

3 The TikZ library

`\usetikzlibrary{florilegium}` draws the species of 2.0 in a TikZ picture, under pdfLaTeX or LuaLaTeX. Under pdfLaTeX it is pure TikZ: every plant, visitor, window and shell is sampled from its genome, grown and painted by pgfmath and TikZ, with no Lua at all. It is slow, about a minute and a half for a strip of three plants 21 cm tall, but it is all TikZ. Under LuaLaTeX the library draws the same plants with florilegium's Lua instead, about a hundred times faster.



Two strips of three plants on one root, from ***specimen-tikz.tex****.*

3.1 Files

The library is two files, `tikzlibraryflorilegium.code.tex` (the drawing) and `tikzlibraryflorilegium.tables.code.tex` (the genome's tables). Put them beside the document, or in your TeX tree. It does not need `florilegium.sty`, and the two can be loaded together. Under LuaLaTeX, its Lua engine needs `florilegium-native.lua`, `florilegium-species.lua`, `florilegium-ink.lua` and `florilegium-pgfmath.lua` as well. Where `florilegium-native.lua` can't be found, the library draws in pure TikZ.

```
\documentclass{article}
\usepackage{tikz}
\usetikzlibrary{florilegium}
\definecolor{ink}{HTML}{2456C4}        % optional: the hue of the palette (Delft blue)
\begin{document}
\begin{tikzpicture}
  \pic at (0,0) {florilegium flower={seed=7, role=hero, size=2.6cm}};
  \pic at (3,-1.3) {florilegium leaf={seed=7, role=hero, size=3.4cm}};
  \pic at (6,-1.3) {florilegium inflorescence={seed=20, role=heath, scale=1.3}};
  \pic at (10,0) {florilegium visitor={seed=3, role=butterfly, size=3cm}};
\end{tikzpicture}
\end{document}
```

3.2 Pics

pic	what it draws	keys
`florilegium flower`	one flower face on, `size` its diameter	`seed role size draw`
`florilegium leaf`	one leaf from its base along +y, `size` its length	`seed role size draw`
`florilegium inflorescence`	the species' cluster from its stalk's base along +y, as large as the margin's at `scale=1`	`seed role scale season draw`
`florilegium plant`	one plant from its root, `size` its height, its branches reaching about `width`	`seed role size width season`
`florilegium plants`	plants on one root, like a margin's main stems, the first `size` tall and the others 60–72% and 36–48% of it, with a pale flower of the first behind them (a fern grows from its crown, so `florilegium fern` draws it, not `plants`)	`plants={3/rose, 17/ umbellifer, 29/mustard}, size width season ghost`
`florilegium fern`	a fern's crown, `size` its longest frond	`seed size season draw`
`florilegium visitor`	a visitor, `size` its wingspan, or its length	`seed role size draw`
`florilegium tracery`	a window of Gothic tracery centered on the origin with its sill on the x axis, `size` its width (the outermost molding included)	`seed role size draw`
`florilegium shell`	a shell centered on the y axis with its base on the x axis, `size` across at most	`seed role size draw`

- `seed` picks the species (1 to 2147483646), and `role` narrows what it may be to `hero`, `spray`, `monocot`, `any` (the default), or a body plan (`rose`, `lily`, `pea`, `daisy`, `umbellifer`, ...). One seed and role is always one species. A seed outside that range or a role that no plant has is an error, and the pic is drawn with seed 1 or role `any`.
- `draw` seeds the drawing, so one species can be drawn many ways; by default it is the species' seed plus one. A plant grows from its species' seed alone, so it has no `draw`.
- `seed`, `draw` and `season` may be anything pgfmath computes, such as `seed=10+\i` in a `\foreach`; a seed's digits after the point are dropped, as `\pgfmathsetseed` drops them.
- `season` is 0.3 for spring, 0.75 for summer (the default) and 1.25 for autumn, and sets each flower's stage, from bud to fruit.
- For a visitor, `role` is the visitor of a kind of flower (`bee`, `butterfly`, `moth`, `bird`, `beetle`, `fly`), one that lives off the flowers (`leaf`, `stem`, `perch`), `any`, or a kind (`ladybird`, `dragonfly`, `snail`, `hummingbird`, ...).

- For tracery, `role` is `window`, `headpiece` (a screen of lights under a flat arch, as the package sets over a section), `rose`, `ornament` (a foil, or a rose), `any`, or a kind (`arcade`, `foil`). The traits are the window's genome: `period`, `arch`, `lights`, `branch`, `figure`, `foils`, `cusps`, `transoms`, `spandrel`, `hood`, `orders` and the rest (`docs/traits.md`), so `traits={period=perpendicular, lights=5, transoms=1}` asks for a Perpendicular window of five lights with a transom. In pure TikZ a window takes about twenty seconds, since the largest circle in each gap of the head is searched for in pgfmath.
- For a shell, `role` is `margin` (the kinds that read well small, as the margin's cabinet draws them), `ornament`, a group (`planispiral`, `bivalve`, `gastropod`), `any`, or a kind (`ammonite`, `nautilus`, `scallop`, `cockle`, `mussel`, `clam`, `oyster`, `whelk`, `turret`, `topshell`, `cowrie`). The traits are the shell's genome: `kind`, `ground`, `pattern`, `view`, `preservation`, the coil's `whorls`, `expansion`, `umbilicus` and `spire`, `sculpture`, `ribs`, `keel`, `septa`, `canal`, `lip` and the rest, so `traits={view=inside}` lays a valve open and `traits={hand=sinistral}` coils a whelk to the left. In pure TikZ a shell takes from one to six seconds.
- `engine` is `auto` (the default), `lua` or `tikz`, for one pic or for all of them with `\pgfkeys{/florilegium/engine=tikz}`.
- `traits` fixes some of the species' or the visitor's traits and leaves the rest to the seed (see your own genome); in `plants`, every plant takes them.
- The colors are the document's `ink` and `accent`, as for the package; without them, Delft blue and copper.

The traits themselves can be read too:

```
\florilegiumspecies{7}{hero}      % sample a species without drawing it
\florilegiumtrait{plan}, \florilegiumtrait{merosity} parts, \florilegiumtrait{inflo}
\florilegiumvisitor{3}{any}       % and a visitor
\florilegiumvisitortrait{kind}
\florilegiumtracery{3}{window}    % and a window of tracery
\florilegiumtracerytrait{period}, \florilegiumtracerytrait{lights} lights
\florilegiumshell{3}{any}         % and a shell
\florilegiumshelltrait{kind}, \florilegiumshelltrait{whorls} whorls
```

3.3 A genome of your own

A pic's `traits` fixes traits by name, and the seed samples the rest. A palmate leaf of seven toothed leaflets, or a simple leaf lobed like a maple's:

```
\pic {florilegium leaf={seed=7, size=4cm, traits={compound=palmate, leaflets=7,
↪  leafmargin=serrate}}};
\pic {florilegium plant={seed=12, role=eudicot, size=9cm, traits={compound=simple,
↪  leafmargin=palmatelobed}}};
\pic {florilegium visitor={seed=3, role=any, size=2cm, traits={kind=ladybird,
↪  spots=14}}};
\florilegiumspecies[plan=rose, color=white]{7}{any}   % the same, without drawing
```

The traits lists every one and what it may be; a name the genome lacks, or a value no plan (or no kind of visitor) can draw, is an error that says what the trait may be. So is a

value only a fern draws fixed on a flowering plant (`inflo=none`, `compound=frond`), and on a fern a leaf tip, edge or outline that its frond has no drawing for (`leafapex=acuminate`). After such an error the pic is drawn as the seed samples it, without the traits. A number is written plainly, `7`, `7.0` or `-0.5`, braced or not (`{7}`); `+7`, `1e1`, `0x7` or an expression is an error, the same in both engines. The fern pic draws a fern, so a flowering plant's `plan` there is an error too. A fixed trait still takes its random draw, so the traits drawn before it are as the seed gave them, and those after it too, unless one that depends on it draws differently (a palmate leaf draws how many leaflets it has, a simple one does not), which moves every later draw along. A trait that depends on a fixed one follows it, and a fixed `plan` (or a visitor's `kind`) brings its own distributions. Botany's rules hold for what the genome samples; a fixed trait is taken as it is, so a lily with toothed leaves is yours to ask for, and a value the drawing has no form for is drawn plainly (another kind's feelers as threads, a toothed edge with no teeth smooth). Both engines fix traits the same way.

`specimen-tikz.tex` draws one of nearly everything, from the strips above to each body plan's flower and leaf, every flower form and kind of cluster, every leaf, ferns, and the visitors.

3.4 Engines

Under pdfLaTeX, and with `engine=tikz` under LuaLaTeX, pgfmath computes every point and TikZ draws it. Under LuaLaTeX, `engine=auto` hands the pic to `florilegium-native.lua`, which takes the same steps with the same random draws from pgf's generator, in floating point instead of pgfmath's arithmetic, and paints into the picture. The two drawings of a seed agree within a fraction of a point; `tools/tikzcheck.lua draw` renders both and compares them pixel by pixel and in total darkness.

one strip of three plants, 21 cm tall	**time**	**PDF**
pdfLaTeX, pure TikZ	107 s	1.5 MB
LuaLaTeX, pure TikZ (`engine=tikz`)	118 s	1.5 MB
LuaLaTeX, Lua engine (the default)	0.9 s	0.6 MB

`tools/bench-tikz.tex`, timed by `make bench` on 2026-11-17 (Intel Core i9-13900K, TeX Live 2023).

3.5 pdfLaTeX's memory

pdfTeX keeps a page's drawing in its main memory until the page is shipped out. A strip of plants in this much detail needs about 7.3 million words of it, more than the 5 million pdfTeX has by default, and a full page of the specimen sheet about 12.5 million. TeX Live reads a larger size from the environment at run time, with no format to rebuild:

```
extra_mem_top=10000000 pdflatex strip.tex
extra_mem_top=20000000 pdflatex specimen-tikz.tex
```

Without it, pdfLaTeX stops with "TeX capacity exceeded, sorry [main memory size]". LuaLaTeX's memory grows as it needs to.

3.6 What is TikZ, and what is not

Everything a pic draws is computed in TeX under pdfLaTeX: the species' traits, sampled with pgf's own random numbers, and every point of every petal, leaf, stem, frond, wing, window and shell. The genome's tables in `tikzlibraryflorilegium.tables.code.tex` are plain TeX data, written once from `florilegium-species.lua` by `tools/tikztables.lua`, so the genome is kept in one place.

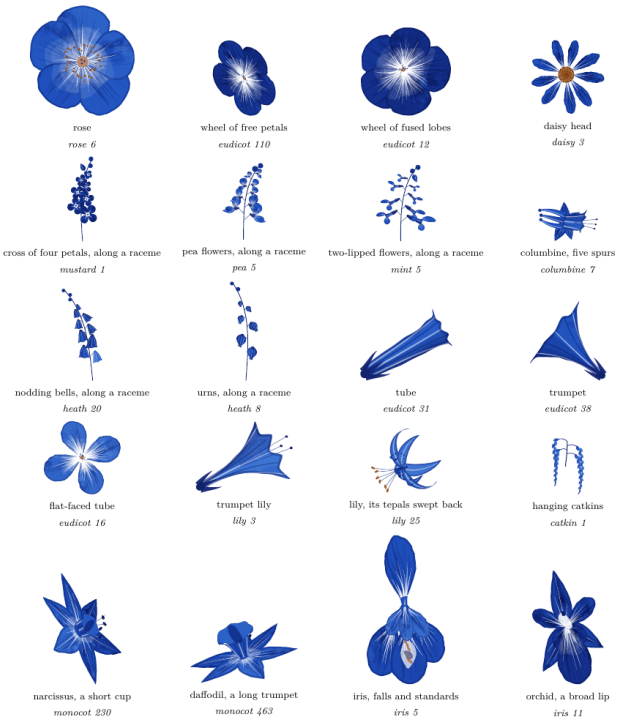
What the library does not do is the page. Growing a margin around the text, the space under the last line, a heading's flower, visitors placed by the plants they came for, and the seasons over a document are the package's, and the package is Lua (LuaLaTeX only).

3.7 A change to pgf at load time

pgfmath's number scanner leaves a name in TeX's string pool for every distinct number it reads, and under pdfLaTeX a few thousand coordinates fill the pool. The library changes one line of it when it loads, so that the lookup behind the name is made only after a leading 0, the only place a base prefix can follow. Nothing else changes, and pgf's own files stay as they are. The change applies only if that line is found in one of the two forms pgf has written it in (pgf 3.1.10, and 3.1.12 in TeX Live 2026). pgf has since fixed the scanner itself (pgf-tikz/pgf#1489, for the release after 3.1.12), and with that pgf the library finds nothing to change and says nothing. Under any other pgf the library leaves the scanner alone and says so in a warning under pdfLaTeX, where a page of plants may then stop with "TeX capacity exceeded, sorry [pool size]". Problems with the change belong to florilegium, not to pgf's authors.

4 The species garden

In 2.0, the plants of a grown margin are not drawn from a fixed set of shapes. Each one is a *species*, a table of traits sampled from a genome. They say what kind of plant it is, the visitor its flowers are for, the flower, how its flowers are clustered, the leaf, the stem and the fruit. A document gets eight species, each page grows four of them, and the animals that come to the page are sampled the same way.



Every flower form, each as its plant holds it, from `specimen-tikz.tex`.

4.1 A genome

A species is 62 traits, always drawn in the same order. The first is the *body plan*, which fixes the clade (monocot, eudicot or fern) and gives every later trait its distribution. There are fourteen flowering plans (lily, iris, rose, mustard, pea, mint, daisy, umbellifer, heath, borage, catkin, columbine, and a generic eudicot and monocot) and the fern.

part	**what the genome decides**
visitor	the pollination syndrome (bee, butterfly, moth, bird, beetle, fly or wind), which weights the color
flower	one of eight colors and fifteen forms (wheel, rose, cross, bell, urn, tube, funnel, salver, two-lipped, pea, orchid, iris, lily, spurred, head); symmetry, fused or free petals and how many; the petal's shape, tip, edge and claw, how far it bends back; guide lines, dots, a blotch or an eye, a pale rim, a corona, spurs, stamens; whether it is held up, sideways or nodding
cluster	alone on its stalk, or a raceme, spike, panicle, thyrse, corymb, simple or compound umbel, forked or coiled cyme, head or catkin; how many flowers, in what order they open, how large they are

part	what the genome decides
leaf	simple, or pinnate, bipinnate, palmate or trifoliate; one of twelve shapes, nine edges, six tips and six bases; pinnate, arcuate, palmate, parallel or forked veins; stalked, stalkless, clasping or sheathing; stipules; alternate, opposite, whorled, in a rosette or in two ranks; curled tips, hairs
stem	upright, sprawling, climbing or woody; its section and taper; tendrils on a climber's leaves
fruit and season	sixteen fruits, from a pea's pod and a rose's hip to a dandelion's clock; an early or a late flowerer
fern	fronds divided once, twice or three times, their outline, pinnae and stalk; the sori beneath, and a fertile frond of another shape

A body plan bundles its traits, so the rules of botany hold by construction. A lily has its parts in threes and its leaves smooth-edged, with parallel veins. A pea flower is two-sided, with five petals and a pod. A cross of petals has four. A catkin has no petals and no visitor, since the wind pollinates it. Only a radially symmetric flower may vary its number of petals from flower to flower, as Damerval and Nadot (2007) found in the buttercup order. `tools/speciescheck.lua` samples thousands of species and fails if any of them breaks a rule.

4.2 In words

A species can describe itself, and the playground writes its page text from these sentences. The eight of the document seed 7:

- A blue daisy head of nineteen rays alone on its stalk, for bees; lobed, narrow leaves; then small dry seeds.
- A five-petaled blue rose in forked cymes, for bees; deeply cut, oval leaves; then capsules.
- A blue wheel of five lobes in a coiled cyme that uncurls, for bees; hairy, smooth-edged, oval leaves; then nutlets.
- Tiny petal-less flowers in hanging catkins, pollinated by the wind; toothed, spoon-shaped leaves; then winged seeds.
- A violet lily of six swept-back tepals along a raceme, for butterflies; smooth-edged, narrow leaves with parallel veins; then capsules.
- A four-petaled nodding white rose in a flat-topped cluster, for flies and hoverflies; leaves of two pairs of toothed leaflets; then stone fruit.
- A blue pea flower along a raceme, for bees; leaves of five pairs of smooth-edged leaflets, climbing by tendrils; then pods.
- A white two-lipped flower in a dense spike, for bees; toothed, narrow leaves, in pairs; then nutlets.

4.3 A genome of your own

Any trait can be fixed and the rest sampled, in the TikZ library's pics (`traits={compound= palmate, leaflets=7}`) and with `\florilegiumspecies[...]`; see the TikZ library and the traits, which lists every trait and what it may be.

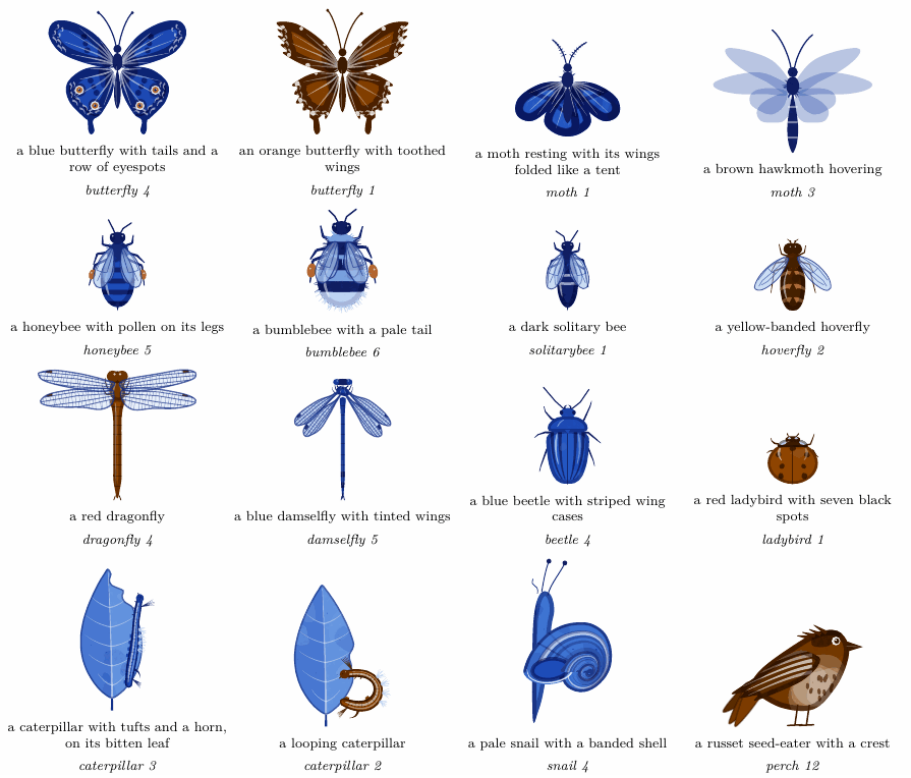
4.4 A document's plants

The document's seed (`\def\florilegiumseed{7}`) picks its *pool* of eight species, two heroes, two sprays, a monocot and three others, with no body plan twice. The heroes are showy, with single flowers or loose clusters painted in the ink. A document without a seed has one pool, the same in every such document, and its pages still differ.

Each page grows four of the eight. The hero takes the tallest main stem and opens its largest flower at the top of the page; a second showy plant takes the second stem, the monocot the third, and a spray runs along the footer. Which hero, which spray and which second plant come to a page is the page's own draw, so the eight recur across a document the way plants recur across a garden. On the last page, the arcs that reach into the space below the text come from the stems in turn. On two pages in five, the document's fern grows from a crown beside the root, two to four fronds leaning into the column, some unrolling, some turned to show their spores.

The growth loop is v1.3's (see how it works). What changes is what it places. Each plant brings its own rows to the loop, which are its inflorescence, buds, smaller sprays, leaves at its nodes, a tendril if it climbs, and, for the hero, big flowers at the ends of its side branches. A branch belongs to the plant whose stem it leaves, so a rose's branches carry roses. Flowers are drawn larger than life, at the size of v1.3's, as an illustrator enlarges a small flower.

4.5 Visitors



The visitors of `specimen-tikz.tex`*, one or two of each kind.*

A visitor is sampled from a genome of its own, which has 15 kinds (butterfly, moth, hawkmoth, honeybee, bumblebee, solitary bee, hoverfly, dragonfly, damselfly, beetle, ladybird, caterpillar, snail, songbird, hummingbird) and 48 traits, such as a wing's tip, edge and tails, its pattern, a bumblebee's bands, a beetle's spots, a snail's shell, a bird's bill, and the pose it is seen in. A butterfly's pattern follows the systems of the nymphalid groundplan, with bands near the body, a central band with its discal spot, a border band, eyespots with their rings and the arcs outside them, and crescents at the edge.

A snail's shell is Raup's coiled tube. A ring the shape of its mouth sweeps round the coiling axis, growing by the shell's expansion each turn and sliding along the axis as far as its spire asks, so a shell can be flat, globular or tall. Seen from the spire's side, each whorl's two edges are where the rings reach farthest across the coil, and the whorls are painted from the mouth inward, each older one over the next, so its rim is the suture. A shell may be banded, ribbed or corded and coils to the left once in twenty; one in a hundred is open-coiled, its last whorl clear of the rest, and three in ten are withdrawn into the shell, its mouth sealed and no foot showing.

Each plant whose flowers have a visitor brings it to the page, so a bee comes to a bee flower and a hummingbird to a red tube, and so on for moths, butterflies, beetles and hoverflies. It flies in near that plant's stems. Off the flowers, a snail climbs a main stem, a seed-eating bird perches on a twig of its own, a caterpillar feeds on a bitten leaf, a dragonfly or a damselfly hunts by the monocot and a ladybird climbs a stem.



300 dpi. A snail on a main stem, and a ladybird climbing another.

A page has about three visitors, as in v1.3, from a random stream of their own, so a page that no visitor came to is exactly the page `novisitors` draws; where a visitor does come, it takes room the plants would have grown into.

4.6 Seasons and headings

With the option `aging` (or `\florilegiumage`), each flower's stage comes from the season, its place in its cluster and the species' phenology, so it is a bud, open, past its best or a fruit. Spring brings buds and fiddleheads, autumn pods, hips, seed clocks and a few copper leaves.

With the option `sections`, a heading gets the flowers of the plant nearest to it, in the accent's copper (buds for a subsection). `\florilegiumbloom[...]` takes `flower`, `bud`, `leaf`, `tendril`, a role (`hero`, `showy`, `monocot`, `spray`) or the name of a body plan on the page (`rose`, `lily`, ...).

4.7 Drawn in v1.3's hand

Every organ is painted as v1.3's primitives were, with a flat wash, darker blotches multiplied over it, pigment pooling at the edge, white streaks lifted out, a few fine veins. Petals, leaves and stems keep v1.3's sizes and weights, so a species page reads like a v1.3 page with more kinds of plant in it. The smallest petals, of which a daisy's flat cluster or a clover head holds hundreds, are drawn more plainly below 1.2 mm, where the detail could not be seen.

A flower is seen as its form and its stalk hold it. It faces the reader when it is held up, turns to a tilt when it is held sideways and shows its back and calyx when it nods; bells, urns, tubes, trumpets, pea and two-lipped flowers are always seen in profile. A bell has a shoulder under its flaring rim, and the shade on its far side follows its curve. A lily whose tepals sweep back is seen from the side and a little from below, the tepals curling back past its stalk and the stamens hanging out under them; a trumpet lily is a long tube that flares at its mouth. Seen in profile, a flower reaches out from its stalk as a solid shape nearly as long as it is wide, so at the top of a stem or alone on a branch it is drawn 0.72 times as large as a flower seen face on. A catkin is a tassel of overlapping scales, lit on one side and shaded on the other, with the paper showing between them. A long strap leaf may arch over toward the side it bends to (a broad one less), and a narrow one may twist edge on and show its paler underside beyond the twist.

The organs are written twice, step for step, in plain Lua (`florilegium-native.lua`), which draws the margin, and in TikZ (`tikzlibraryflorilegium.code.tex`), which draws them on their own under pdfLaTeX (see the TikZ library).

4.8 One seed, one species, in Lua or TikZ

Both sides draw from pgf's own random generator, which `florilegium-pgfmath.lua` replays exactly. Every choice is a whole-number draw, and a trait that is a real number is the very number pgfmath computes from its draw, so `\florilegiumspecies{7}{hero}` in TikZ and `species.sample(7, "hero")` in Lua find the same species (`tools/tikzcheck.lua` compares their choices for a thousand seeds). The TikZ tables are generated from `florilegium-species.lua` by `tools/tikztables.lua`, so the genome is written once.

The drawing itself is computed in pgfmath's arithmetic in TikZ and in floating point in Lua, so the two drawings of a seed agree within a fraction of a point rather than byte for byte. `tools/tikzcheck.lua draw` renders both and compares them, pixel by pixel and in total darkness.

4.9 Sources

The trait tables follow research notes made for this project, drawn from botanical glossaries and the papers below.

- The rule that a variable number of petals goes with radial symmetry is the finding of C. Damerval and S. Nadot, *Evolution of perianth and stamen characteristics with respect to floral symmetry in Ranunculales* (Annals of Botany 100, 2007), in the buttercup order; here it holds for every body plan.
- Flowers and visitors are paired by the pollination syndromes of the U.S. Forest Service's *Pollinator Syndromes* page (its text; the photograph there is someone else's), as weights rather than rules, since real flowers draw many visitors (C. B. Fenster and others, *Pollination syndromes and floral specialization*, Annual Review of Ecology, Evolution, and Systematics 35, 2004).
- A snail's shell is the coiled tube of D. M. Raup, *Geometric analysis of shell coiling: general problems* (Journal of Paleontology 40, 1966), its ring placed as T. Okabe and J. Yoshimura reparameterize Raup's model in *Optimal designs of mollusk shells*

from bivalves to snails (Scientific Reports 7, 2017), with the spire lower for a fast-widening coil, the negative relation they report. It is drawn from its whorls' edges, the simpler method for line drawings that the research notes describe.

- Heads and daisy discs are packed on Vogel's spiral (H. Vogel, *A better way to construct the sunflower head*, Mathematical Biosciences 44, 1979).
- A butterfly's pattern systems follow the nymphalid groundplan proposed by B. N. Schwanwitsch (*On the ground-plan of wing-pattern in nymphalids and certain other families of the rhopalocerous Lepidoptera*, Proceedings of the Zoological Society of London, 1924) and by F. Süffert (*Zur vergleichenden Analyse der Schmetterlingszeichnung*, Biologisches Zentralblatt 47, 1927; checked against the papers that cite it, not the original).

5 Traits

The traits a species, a visitor, a window of tracery and a shell are sampled with, in the order they are drawn, and what each may be fixed to: one of the names listed, or a number in the range given (a whole number where it says so). Fix them with `\florilegiumspecies[...]`, `\florilegiumvisitor[...]`, `\florilegiumtracery[...]`, `\florilegiumshell[...]` or a pic's `traits` key; the TikZ library shows how. `clade` and `group` follow from the plan and the kind and are not fixed themselves.

This page is written by `tools/tikztables.lua` from `florilegium-species.lua`.

5.1 A species

trait	what it may be
`plan`	`borage`, `catkin`, `columbine`, `daisy`, `eudicot`, `fern`, `heath`, `iris`, `lily`, `mint`, `monocot`, `mustard`, `pea`, `rose`, `umbellifer`
`syndrome`	`bee`, `beetle`, `bird`, `butterfly`, `fly`, `moth`, `none`, `wind`
`color`	`blue`, `green`, `orange`, `pink`, `red`, `violet`, `white`, `yellow`
`form`	`bilabiate`, `campanulate`, `cruciform`, `funnelform`, `head`, `iris`, `lily`, `none`, `orchid`, `papilionaceous`, `rosaceous`, `rotate`, `salverform`, `spurred`, `tubular`, `urceolate`
`symmetry`	`bilateral`, `none`, `radial`
`fused`	a whole number from 0 to 1
`merosity`	a whole number from 0 to 21
`merovar`	a whole number from 0 to 1
`petalshape`	`lanceolate`, `linear`, `none`, `oblong`, `obovate`, `orbicular`, `spatulate`
`petalaspect`	a number from 0.9 to 6
`apex`	`acuminate`, `acute`, `bifid`, `emarginate`, `fringed`, `none`, `rounded`
`petalmargin`	`crenate`, `entire`, `fimbriate`, `laciniate`, `none`, `undulate`
`petalamp`	a number from 0 to 0.06
`claw`	a number from 0 to 0.5
`reflex`	a number from -80 to 30

trait	what it may be
overlap	a number from 0 to 0.4
cup	a number from 0 to 1
guides	blotch, dots, eye, lines, none
guidecount	a whole number from 0 to 6
picotee	a whole number from 0 to 1
corona	cup, none, trumpet
spurs	all, none
stamens	exserted, included, none
orient	erect, horizontal, nodding
inflo	catkin, corymb, cumbel, dichasium, head, monochasium, none, panicle, raceme, solitary, spike, thyrse, umbel
count	a whole number from 0 to 80
rays	a whole number from 0 to 20
depth	a whole number from 0 to 3
openorder	base, center, none, outside
siderule	alternate, none, same
coil	a number from 0 to 1
size	a number from 0 to 90
compound	bipinnate, frond, palmate, pinnate, simple, trifoliate
leaflets	a whole number from 0 to 9
leafshape	cordate, deltoid, elliptic, hastate, lanceolate, linear, oblong, obovate, orbicular, ovate, reniform, sagittate
leafaspect	a number from 0.6 to 20
leafmargin	crenate, dentate, doubly, entire, lobed, palmatelobed, pinnatifid, serrate, undulate
teeth	a whole number from 0 to 28
dissection	a number from 0 to 0.92
leafapex	acuminate, acute, emarginate, mucronate, obtuse, rounded
leafbase	auriculate, cordate, cuneate, oblique, rounded, truncate
venation	arcuate, forked, palmate, parallel, pinnate
attachment	clasping, none, petiolate, sessile, sheathing
stipules	leafy, none, small
arrangement	alternate, crown, distichous, opposite, rosette, whorled
curl	a number from -0.3 to 0.6
twist	a number from 0 to 50
taper	a number from 0.4 to 1
turns	a whole number from 0 to 1
habit	climbing, erect, sprawling, woody
section	prickly, ribbed, round, square
hairy	a whole number from 0 to 1
tendrils	a whole number from 0 to 1

trait	what it may be
fruit	achene, berry, capsule, drupe, follicle, hip, legume, nut, nutlets, pappus, pome, samara, schizocarp, silicle, silique, spores
phenology	a number from -0.15 to 0.15
division	a whole number from 0 to 3
pinnae	a whole number from 0 to 26
outline	deltoid, lanceolate, none, oblong, ovate
stipe	a number from 0 to 0.4
sori	dots, lines, marginal, none
dimorphic	a whole number from 0 to 1

5.2 A visitor

trait	what it may be
kind	beetle, bird, bumblebee, butterfly, caterpillar, damselfly, dragonfly, hawkmoth, honeybee, hoverfly, hummingbird, ladybird, moth, snail, solitarybee
size	a number from 4 to 140
tone	a number from 0.26 to 0.5
ground	copper, dark, ink, pale
pose	closed, cross, curl, flat, fly, folded, glide, hover, loop, open, perch, rest, spread, straight, tent, visit, walk
apex	angular, falcate, pointed, rounded
wingedge	scalloped, smooth, toothed
tails	a whole number from 0 to 2
basal	a whole number from 0 to 1
central	band, none, spots
discal	a whole number from 0 to 1
border	band, eyes, none, spots
eyes	a whole number from 0 to 7
rings	a whole number from 0 to 3
parafocal	a whole number from 0 to 1
lunules	a whole number from 0 to 2
veins	a whole number from 0 to 1
antenna	clubbed, comb, elbowed, feathery, short, thread
bands	a whole number from 0 to 8
hair	a number from 0 to 1
pollen	a whole number from 0 to 1
build	a number from 0.1 to 0.9
paletail	a whole number from 0 to 1
tint	clear, tinted
stigma	a whole number from 0 to 1

trait	what it may be
pattern	plain, spots, stripes
spots	a whole number from 0 to 22
spotsize	a number from 0 to 0.2
stripes	back, none, side
tufts	a whole number from 0 to 1
horn	a whole number from 0 to 1
whorls	a number from 3.5 to 6
expansion	a number from 1.6 to 3.2
spire	a number from 0.1 to 1.2
hand	dextral, sinistral
shellbands	a whole number from 0 to 5
lip	a whole number from 0 to 1
extension	a number from 0.4 to 1
bill	conical, curved, straight
crest	a whole number from 0 to 1
tail	a number from 0.3 to 0.5
aperture	a number from 0.85 to 1.3
suture	a number from 0.15 to 0.8
sculpture	cords, ribs, smooth
ribs	a whole number from 0 to 24
opencoil	a whole number from 0 to 1
withdrawn	a whole number from 0 to 1

5.3 A window of tracery

trait	what it may be
kind	arcade, foil, headpiece, rose, window
period	curvilinear, early_english, flamboyant, geometric, perpendicular, rayonnant
masonry	bar, plate
arch	drop, equilateral, fourcentered, lancet, none, ogee, round, segmental
excess	a number from 0 to 1.6
rise	a number from 0 to 0.4
ogee	a number from 0 to 0.7
shoulder	a number from 0 to 0.25
jamb	a number from 0 to 2.2
lights	a whole number from 0 to 10
split	binary, center, flat
branch	Y, flowing, intersecting, none, panel, reticulated, screen, subarch
depth	a whole number from 0 to 3

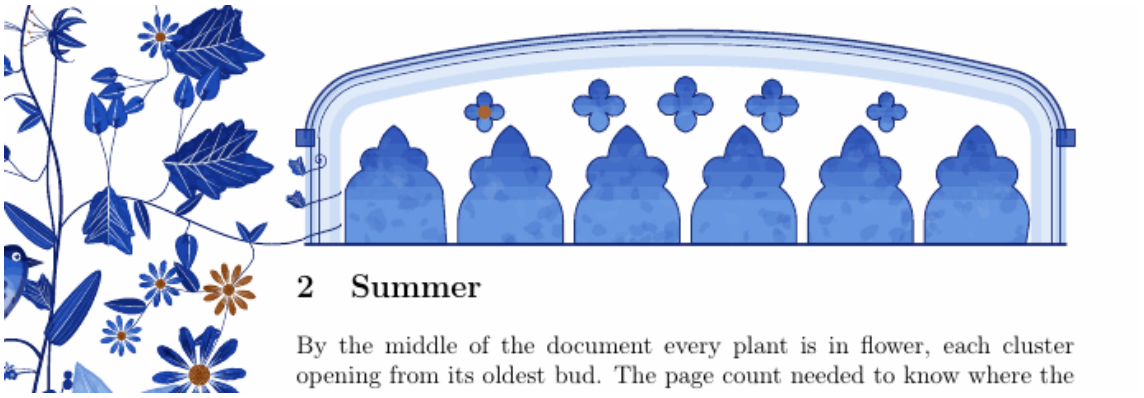
trait	what it may be
setdown	a number from 0 to 0.12
bar	a number from 0.012 to 0.03
border	a number from 0.015 to 0.06
transoms	a whole number from 0 to 2
figure	dagger, foiled, mouchettes, none, oculus, soufflet, triangle
foils	a whole number from 0 to 8
foilshape	pointed, round
cusps	a whole number from 0 to 4
cuspdepth	a number from 0.12 to 0.28
orders	a whole number from 1 to 3
hood	none, plain, stops
spandrel	blank, dagger, foliage, trefoil
spokes	a whole number from 0 to 16
rings	a whole number from 0 to 2
oculus	a number from 0 to 0.3
tone	a number from 0.3 to 0.5
accent	center, none, stops

5.4 A shell

trait	what it may be
kind	ammonite, clam, cockle, cowrie, mussel, nautilus, oyster, scallop, topshell, turret, whelk
size	a number from 12 to 220
tone	a number from 0.28 to 0.42
ground	dark, ink, pale
pattern	bands, dots, flammules, none, rays, zigzags
contrast	a number from 0 to 1
view	back, flank, inside, mouth, outside
preservation	mold, nacre, pyrite, shell
involution	evolute, intermediate, involute
whorls	a number from 3 to 15
expansion	a number from 1.15 to 3.6
umbilicus	a number from 0 to 0.45
spire	a number from 0 to 5
aperture	a number from 0.8 to 1.6
hand	dextral, sinistral
sculpture	branching, cancellate, cords, layers, nodes, ribs, ridges, smooth, tubercles
ribs	a whole number from 0 to 48
cords	a whole number from 0 to 7
ridges	a whole number from 0 to 14

trait	what it may be
`keel`	`grooved`, `keel`, `none`
`septa`	`ammonitic`, `ceratitic`, `goniatitic`, `none`
`broken`	a whole number from 0 to 1
`aspect`	a number from 0.4 to 1.2
`beak`	a number from 0 to 0.5
`ears`	`equal`, `unequal`
`inflation`	a number from 0.2 to 0.8
`shoulder`	`angular`, `none`, `rounded`
`suture`	a number from 0 to 0.7
`canal`	`long`, `short`
`lip`	`flared`, `plain`, `thick`, `toothed`
`folds`	a whole number from 0 to 3

6 Gothic tracery



Since 2.1.0 the margin draws stone as well as plants. A window of Gothic tracery is sampled from a genome of its own, the way a plant is. It goes over a section heading as a headpiece, a screen of lights under a flat arch. The garden sends a branch to it, and a vine twines up the jamb. The same windows are TikZ pics, drawn in pure TikZ under pdfLaTeX, and a decorated initial can open as a cusped arch.

6.1 A window's genome

A window has 30 traits, sampled in a fixed order from pgf's generator. One seed is one window, in Lua and in TikZ alike (the traits lists them all). The first trait is the kind, chosen by the window's role on the page. The second is the period, which sets most of the rest, as a body plan sets a plant's.

kind	role	what it is
`headpiece`	`headpiece`	a wide, shallow arch over five to eight lights, their cusped heads rising into it, small foils in the stone between them
`arcade`	`headpiece`	five to ten bays side by side under a straight molding, trefoils between them
`window`	`window`, `frame`	a tall window of one to seven lights, its head branching as its period does
`rose`	`rose`, `ornament`	spokes from a foiled eye to the rim, in one ring or two
`foil`	`ornament`	a foiled circle alone, three to eight lobes, round or pointed

The periods are Rickman's names for English Gothic, with the French rayonnant and flamboyant beside them. Each draws its own arches and heads.

- *Early English* has lancets and equilateral arches, plate tracery cut through the slab, and a single oculus or foiled circle in the head.
- *Geometric* has equilateral arches over sub-arches, with a foiled circle or a spherical triangle above them and trefoils in the spandrels. Its mullions may fork in a Y or cross.
- *Curvilinear* has drop and ogee arches, daggers, mouchettes and soufflets. The lights' ogee heads can repeat up the head as a net (*reticulated*), or mouchettes can *flow* in the head.
- *Perpendicular* has four-centered arches. The mullions run straight up to the arch through a row of panels, and transoms cross the lights.
- *Rayonnant* has equilateral arches over sub-arches and round foils in several orders.
- *Flamboyant* has ogee arches, flowing heads and pointed foils.

The rest follow in their order of sampling. The arch and its excess (radius over span). A four-centered arch's rise and shoulders. The height of the jambs. How the lights split under their sub-arches, in two halves, a center light with the rest each side, or one by one. How deep the sub-arches go and how far they are set down. The widths of the bars and the border. Transoms. The figure in the head and its foils. The cusps in each light's head and their depth. The orders round the arch, the hood mold and its stops, what fills the spandrels, the wash's tone, and where the copper goes.

Rules keep a window buildable. There are no more sub-arches than lights, no cusps on a segmental head, transoms only in the Perpendicular, and a screen only on a headpiece. Every window can also say what it is, through `florilegium.tdescribe`:

> A geometric window of three lights under a sexfoil, in an equilateral arch of two orders with a hood mold ending in stops, the lights trefoiled, trefoils in the spandrels.
>
> A Perpendicular headpiece of six lights paneled to the arch, in a four-centered arch, crossed by a transom, the lights cinquefoiled, foliage in the spandrels.

6.2 On the page

```
\usepackage[grown,headpieces]{florilegium}   % a headpiece over every \section
...
\florilegiumheadpiece                         % or one here, by hand
\florilegiumheadpiece[seed=7, width=10cm, traits={period=perpendicular}, vine=none]
```

The option `headpieces` puts one over every `\section` and `\section*`. It goes after the heading's space above and stays with its title on the page (standard classes). `\florilegiumheadpiece` sets one where it stands, in a box as wide as the line with the sill on the baseline. Its keys are `seed` (by default the k-th of the document, like an ornament), `role` (`headpiece`, or `window`, `rose` and the rest for something else at that width), `width`, `traits` (any of the genome's, fixed, as in your own genome) and `vine`.

With the margin on, the headpiece is not drawn where the command stands. The command leaves a mark, and the headpiece is drawn at shipout, when the page knows which side its margin is on. A vine then twines up the jamb on that side, a helix seen side on round the shaft of moldings, with the leaves of the nearest plant on it. That plant sends a branch from the margin to the vine's foot. On the right-hand pages of a two-sided document it is the right jamb. `vine=auto` does all this; `left`, `right` and `none` choose. Under `nomargin`, and on a page that `\florilegiumoff` or `\florilegiumhide` leaves without its margin, the headpiece is drawn in place without a vine.

6.3 The initial's arch, and ornaments

`\florilegiuminitialframe{arch}` opens the tile of every initial that follows as a cusped flat arch, with stone in the spandrels round it. `plain` is the square again. `\florilegiumornament` takes `trefoil`, `quatrefoil`, `cinquefoil`, `sexfoil` and `rose` beside the plants' primitives.

6.4 In TikZ

```
\usetikzlibrary{florilegium}
\pic {florilegium tracery={seed=3, role=window, size=4cm}};
\pic {florilegium tracery={seed=5, role=headpiece, size=12cm, traits={branch=screen,
↪  foils=4}}};
\florilegiumtracery{3}{window}   % sample one without drawing it, then
\florilegiumtracerytrait{period}
```

The pic draws a window centered on the origin with its sill on the x axis. `size` is its width, the outermost molding included. Under LuaLaTeX `florilegium-tracery.lua` draws it in a fraction of a second. Under pdfLaTeX pgfmath draws the same window step for step in about twenty seconds, since the largest circle in each gap of the head is found by a search in fixed-point arithmetic. The two agree within a pixel at 150 dpi (`tools/tikzcheck.lua draw tracery`). Page 9 of `specimen-tikz.pdf` shows a window of every period and every way a head branches.

6.5 How it is drawn

An arch is a chain of circular arcs. Only the left half is computed, and it is mirrored about the axis. A round or two-centered arch is one arc. A four-centered arch is two, the shoulders struck from the springing and the crown from a center on the axis below them. An ogee is two as well, and its upper arcs reverse above the inflection. The bars, the orders and the hood are offsets of the chain: the radii grow or shrink, and the ends are found again on the jamb and the axis. An ogee's ring is struck again from its inflection, since parallel arcs would meet in a spire above the apex.

A light's head is the arch of the window's manner, flattened step by step (equilateral, drop, round, segmental) until it fits under the arch above it. Its cusps follow Havemann and Fellner. Each side of the head is cut into lobes. A lobe is a circle tangent to the arch, at the outer end of the first and last lobes and at the middle of the others, and it curls in to a cusp between them. A foiled circle is the same authors' construction: n lobes tangent to the circle and to each other, one standing on top of the axis. Pointed foils make each lobe two arcs, from circles moved out along the lines to the tangent feet.

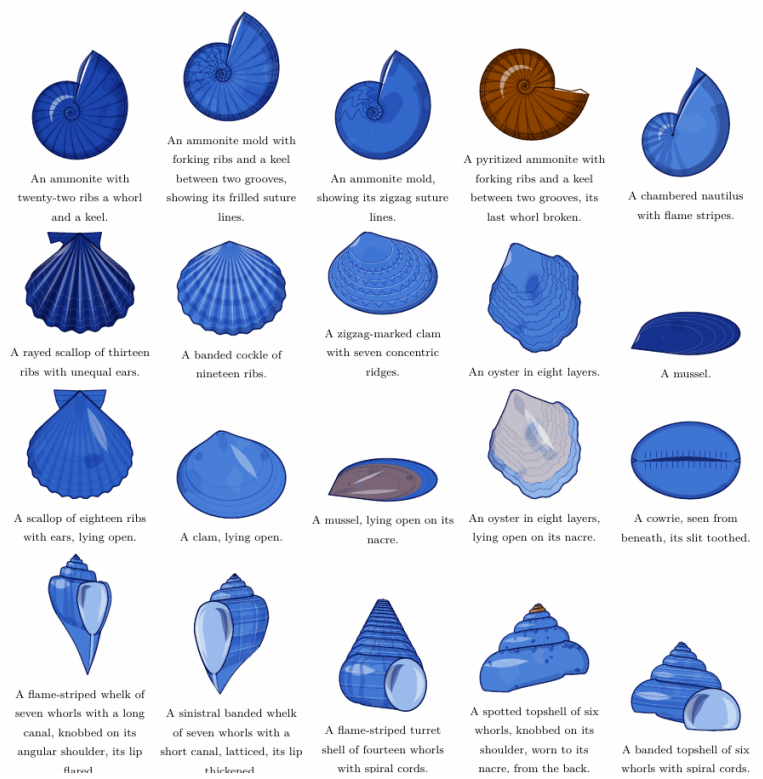
Where stone is left, between sub-arches, heads or in the spandrels, a figure goes into the largest circle that fits there. The circle is found by a search over a grid of signed distances to the arches, circles and half-planes that bound the room. The figure is a foiled circle, an oculus, a spherical triangle, a dagger whose tail reaches for the apex, a pair of mouchettes, a soufflet, or a sprig of three leaflets. Flowing tracery places its figures that way in turn, a pair of mouchettes curling up to the apex first. A reticulated head repeats the lights' ogee in rows staggered by half a light, each row springing where the one below reaches its apexes.

Every opening is washed in the ink, darker toward the top in six faint bands, and granulated with blotches drawn from pgf's generator. Then it is outlined in the pen's line. A bar through stone is a stroke in the ink with a stroke of paper over it, so bars that cross join cleanly. The shaft of moldings is painted as a roll, washed pale and shaded darker toward both edges, so the vine has something to wrap. How much is drawn follows the width of a light on the page. Under 8 mm there are no cusps, under 5 plain figures and one order, and under 3 the arch and its main figure alone.

6.6 Sources

- The periods are Thomas Rickman's, from *An Attempt to Discriminate the Styles of English Architecture* (1817), which gave the styles the names still in use.
- The cusped heads and foiled circles follow the constructions in Sven Havemann and Dieter W. Fellner, *Generative Parametric Design of Gothic Window Tracery* (VAST 2004, the 5th International Symposium on Virtual Reality, Archaeology and Cultural Heritage).
- Daggers, mouchettes, soufflets, reticulated and flowing tracery, transoms, hood molds and the rest come from research notes made for this project, from glossaries of Gothic architecture.

7 Shells



Since 2.1.0 the margin has shells as well as plants. A shell is sampled from a genome of its own, the way a plant is: an ammonite or a nautilus, a scallop, cockle, mussel, clam or oyster, a whelk, turret shell or topshell, or a cowrie. Each document has a cabinet of four, and on some pages a few of them lie on the ground at the foot of the plants, as the Dutch flower painters laid shells beside their bouquets. The shells theme gives them the whole margin. The same shells are TikZ pics, drawn in pure TikZ under pdfLaTeX.

7.1 A shell's genome

A shell has 32 traits, sampled in a fixed order from pgf's generator. One seed is one shell, in Lua and in TikZ alike (the traits lists them all). The first trait is the kind, chosen by the shell's role, and the kind sets its group.

group	kinds	how it is seen
`planispiral`	`ammonite`, `nautilus`	from the side, down the axis it coils round
`bivalve`	`scallop`, `cockle`, `mussel`, `clam`, `oyster`	one valve, its beak up, from the outside or lying open
`gastropod`	`whelk`, `turret`, `topshell`, `cowrie`	from the side with the axis upright, mouth or back to us; a cowrie from above or beneath

The roles are `margin` (the kinds that read well small, for the margin's cabinet), `ornament`, a group, `any`, or a kind. Then come what every shell has: its real size in millimeters, its

tone and ground (the ink's, pale, dark), a color pattern (bands, rays, flame stripes, zigzags, spots) and its strength, how it is seen, and how it is preserved (a shell, a mold showing its suture lines, pyrite, worn through to the nacre). After that each group's own traits follow. For a coil those are David Raup's numbers: how many whorls, how fast the tube widens each turn (W), how far its inner edge stands from the axis (D), and how far the coil is drawn down the axis for a spire (T). Then the sculpture (ribs, forking or knobbed, spiral cords, a lattice, knobs on the shoulder, concentric ridges, an oyster's layers), an ammonite's keel and its kind of suture line, a broken last whorl, a valve's outline and ears, a whelk's shoulder, canal, lip and the folds on its columella, and the hand it coils to.

Rules keep a shell possible. A coil has W over 1 and D from 0 up to 1, and its whorls touch, which is W times D at most 1. Only a whelk or a turret shell coils to the left. Only an ammonite is a mold or pyrite, and suture lines show only on a mold. Only a whelk has a canal and folds, and only a cowrie a toothed slit. Every shell can say what it is, through `florilegium.shdescribe`:

> A flame-striped whelk of seven whorls with a short canal, knobbed on its shoulder.
>
> An ammonite mold with thirty-six ribs a whorl, showing its saw-toothed suture lines.

7.2 On the page

On one page in three of the species garden, one to three of the document's cabinet lie on the ground, beside the root or along the band at the foot of the page. Each is sized from its real size, from 6 mm to 15 mm, so it stays in scale with the plants, and tilted as it fell: a coil or a cowrie nearly upright, a valve tipped over, a spired shell lying on its side. A soft shadow falls to its lower right. They lie under the stems, so the footer's vine and its leaves pass in front of them. The cabinet is drawn once for the whole document, four shells of different kinds from at least two groups and at most one in the copper, so a reader sees the same collection come back. A page without shells is the same page as before, and the option `noshells` leaves them out everywhere.

`\florilegiumornament` takes `scallop`, `ammonite`, `nautilus`, `whelk` and `cowrie`, each a shell of that kind sampled from the ornament's seed.

With `theme=shells` the margin is shells and nothing else: strands of wrack from a pebble in the corner, the cabinet low beside them, and the page's own shells gathering along the wrack. Themes describes it.

7.3 In TikZ

```
\usetikzlibrary{florilegium}
\pic {florilegium shell={seed=3, role=ammonite, size=3cm}};
\pic {florilegium shell={seed=3, role=scallop, size=3cm, traits={view=inside}}};
\florilegiumshell{3}{any}   % sample one without drawing it, then
\florilegiumshelltrait{kind}
```

The pic draws a shell centered on the y axis with its base on the x axis, `size` across at most. Under LuaLaTeX `florilegium-shell.lua` draws it in a fraction of a second.

Under pdfLaTeX pgfmath draws the same shell step for step in one to six seconds, the ammonites the longest. The two agree within a pixel at 150 dpi (`tools/tikzcheck.lua draw shells`). Page 10 of `specimen-tikz.pdf` shows every kind.

7.4 How it is drawn

A coil is Raup's tube. Each turn the ring is W times larger and turned a full turn about the axis, so a ring a degrees along the coil is W to the power a/360 times the first. Its place follows Okabe and Yoshimura, who start from a ring of radius 1 centered y0 from the axis, y0 = (1 + D)/(1 − D), and x0 = T y0 down it.

An ammonite or a nautilus is seen down its axis, so it is flat drawing. A whorl is the band between two spirals, and the next whorl, W times wider, covers its outer part as far as D lets it. What shows of each whorl is the band from its own inner edge to the next whorl's, so the bands tile the disc and the line between two of them is one spiral. Each band is washed, shaded along both edges and lit on its upper left, then gets its ribs, a nautilus's flame stripes or a mold's suture lines, which are lobes and saddles across the band, as deep as they are wide, zigzag, toothed or frilled by kind.

A valve is drawn from its outline. The outline is an ellipse and the beak, joined by the two lines from the beak that just touch the ellipse. A beak well above it makes a scallop's fan, one just over it a cockle's or a clam's rounded umbo, and one low at an end a mussel's wedge. A valve grows at its edge, so a growth line is the margin shrunk toward the beak. A rib runs from the beak to the margin and scallops it. Inside, a valve shows its rim, the line where the mantle met it, the muscle scars, the hinge's teeth and, for a mussel or an oyster, nacre in the copper.

A whelk, turret shell or topshell stands with its axis upright, turned a little so its mouth faces forward. Each whorl shows the front half of its turn. Painted oldest first, each whorl's top edge is the suture on the whorl above. The mouth is seen face on, porcelain going dark into the shell. A whelk's ring is an egg drawn down to its canal. A cowrie has no coil to draw: it is a glossy egg, spotted or banded from above, its toothed slit from beneath.

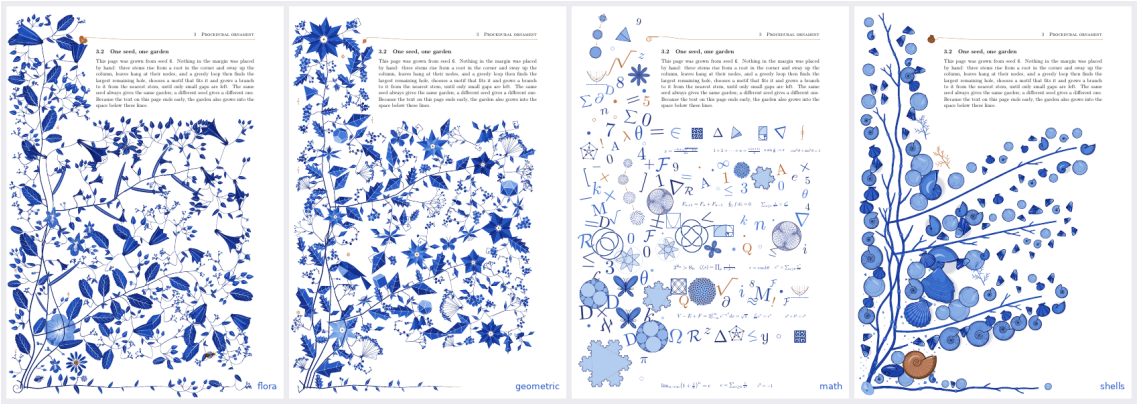
How much is drawn follows the shell's size on the page. Under 12 mm there is no mottle and no suture lines, and under 5 mm only the wash and the lines.

7.5 Sources

- The coil is David M. Raup's model, from *Geometric analysis of shell coiling: general problems* (Journal of Paleontology, 1966).
- The ring's place follows Takuya Okabe and Jin Yoshimura's reparameterization of it, in *Optimal designs of mollusk shells from bivalves to snails* (Scientific Reports, 2017).
- The rule that the whorls touch, W times D at most 1, is as George R. McGhee states it in *Limits in the evolution of biological form* (Interface Focus, 2015).
- Shells beside flowers are an old idea: Balthasar van der Ast painted them, as in his *Flowers in a Wan-Li Vase, with Shells* in the Mauritshuis.

- The kinds, their sculpture and the rest come from research notes made for this project, and nothing is traced from a plate.

8 Themes



Seed 6 four times: the species garden, with `theme=geometric`*, with* `theme=math` *and with* `theme=shells`*.*

```
\usepackage[grown,theme=geometric]{florilegium}   % or theme=math, theme=shells; the
↪  whole document
\florilegiumtheme{math}                            % or from the page this stands on
```

The growth loop never knew what it was drawing. It reads a table of motifs (the size of the disc each one takes, a weight, a function that draws it) and calls every primitive by name. A theme is one Lua file, `florilegium-theme-<name>.lua`, that replaces some of those primitives and may add rows to the table, or brings a composition of its own. The geometric theme grows v1.3's garden, with its hand-designed kinds, and draws it in its own way; the species belong to the unthemed margin. The math and shells themes lay out the whole page themselves.

8.1 Geometric

`theme=geometric` is v1.3's plant cut from flat shapes (`florilegium-theme-geometric.lua`). It grows by v1.3's loop from v1.3's motifs, so the plant is v1.3's and the drawing is new; the crystals among them take some of the room, so a seed's layout is not quite v1.3's. The stems run straight between their nodes, the leaves are kites and toothed polygons folded into a light and a dark facet with straight white veins, the flowers are rosettes of rhombi or layered star polygons, the tendrils square spirals, the bird and the butterfly low-poly. The colors are flat tones of the ink, with no wash, and crystals (Platonic solids, flat-shaded like cut stones) grow among the flowers. A page's margin is about a tenth of the size of a v1.3 page's in the PDF, and a sixteenth of a species page's (`florilegium-grow.tex`, measured 2026-11-05).



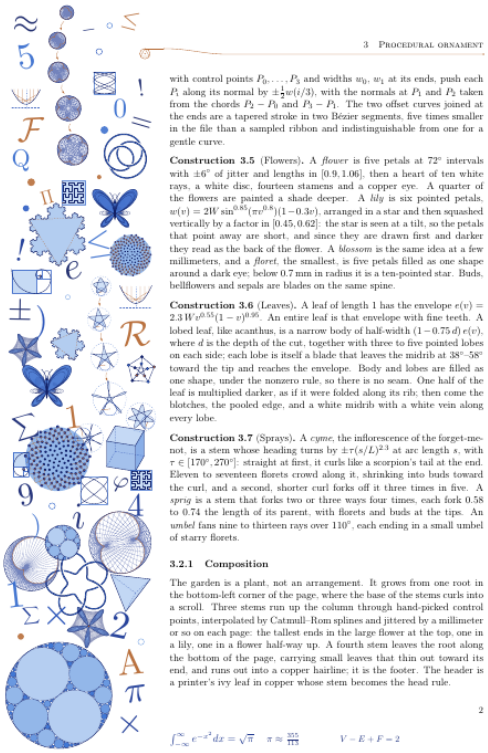


8.2 Math

`theme=math` is no plant at all (`florilegium-theme-math.lua`, drawing from `florilegium-figures.lua`). Mathematics cascades down the margin and across the bottom of the page, overlapping a little so it blends. A large figure sits in the corner where the

column meets the bottom: an Apollonian gasket, a deep Koch snowflake, Vogel's disc, a polyhedron. Down the column run one or two *families*, figures that change as they go, joined by small copper arrows. The Koch snowflake gains a level, a polygon gains sides on its way to the circle, the cube truncates into the octahedron, chords k → mk mod n turn from a cardioid into a nephroid, and Vogel's disc packs evenly only at the golden angle.

Equations that hold (e^{iπ} + 1 = 0, V − E + F = 2, ...) run along the bottom and under the text on the last page. Everything else, largest hole first, is figures (Platonic solids, knots, Hilbert curves, Lissajous curves, hypotrochoids, Maurer roses, the Petersen graph, ...), letters, numerals and symbols set by TeX at many sizes and a slight tilt, and dots. It fills whatever space the page leaves, like the garden; `density` sets how much there is.



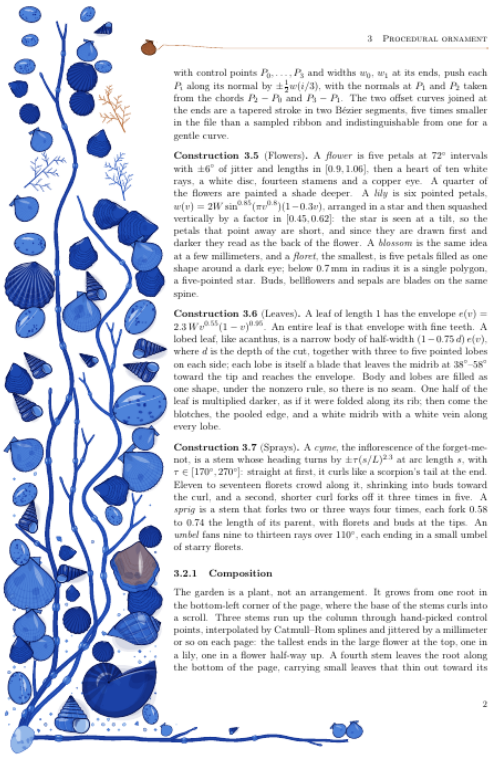
8.3 Shells

`theme=shells` is no plant either (`florilegium-theme-shells.lua`). The margin is a strip of the shore seen from above. Strands of wrack lie from a pebble in the corner up the column and along the foot of the page. Each is a flat strap with a midrib that forks as it goes, with air bladders in pairs and swollen tips, the way bladderwrack grows, and the shells lie among them.

Every shell is sampled from a genome, as a plant is, and drawn from it by `florilegium-shell.lua`: an ammonite or a nautilus, a scallop, cockle, mussel, clam or oyster, a whelk, turret shell, topshell or cowrie. The document's cabinet of four, the same four that lie on the ground on some of the species garden's pages, lies lowest, the largest nearest the corner, so a reader sees the same collection on every page. Then the page draws five kinds of its own and lays them where there is room, largest hole first and those near the wrack first, as the garden's flowers grow from its stems. They are large toward the corner and

small up the column and along the foot, they overlap a little, and now and then one is tucked half under its neighbors. Which kind goes where follows how large it grows, and a kind gets rarer the more of it there is. A tuft of fine weed in the accent, sometimes one or two more in the ink, and grit and broken shell along the bottom finish the page. Each shell casts a soft shadow to its lower right. On a mirrored page the shells are drawn the right way round, since a whelk's coil has a hand.

A small copper scallop stands beside each heading (option `sections`) and starts the head rule, and `\florilegiumbloom[whelk]` lays a shell of that kind, or of a group (`planispiral`, `bivalve`, `gastropod`). The theme has no seasons and no visitors; `density` thins it down to a single strand and a few shells at `0.05`.


3 Procedural ornament

with control points $P_0,\dots,P_3$ and widths w_0, w_1 at its ends, push each P_i along its normal by $\pm\frac{1}{2}w(i/3)$, with the normals at P_1 and P_2 taken from the chords P_2-P_0 and P_3-P_1. The two offset curves joined at the ends are a tapered stroke in two Bézier segments, five times smaller in the file than a sampled ribbon and indistinguishable from one for a gentle curve.

Construction 3.5 (Flowers)**.** A *flower* is five petals at 72° intervals with ±6° of jitter and lengths in $[0.9, 1.06]$, then a heart of ten white rays, a white disc, fourteen stamens and a copper eye. A quarter of the flowers are painted a shade deeper. A *lily* is six pointed petals, $w(v) = 2W\sin^{0.85}(\pi v^{0.8})(1-0.3v)$, arranged in a star and then squashed vertically by a factor in $[0.45, 0.62]$; the star is seen at a tilt, so the petals that point away are short, and since they are drawn first and darker they read as the back of the flower. A *blossom* is the same idea at a few millimeters, and a *floret*, the smallest, is five petals filled as one shape around a dark eye; below 0.7 mm in radius it is a single polygon, a five-pointed star. Buds, bellflowers and sepals are blades on the same spine.

Construction 3.6 (Leaves)**.** A leaf of length 1 has the envelope $e(v) = 2.3\,We^{0.55}(1-v)^{0.95}$. An entire leaf is that envelope with fine teeth. A lobed leaf, like acanthus, is a narrow body of half-width $(1-0.75\,d)\,e(v)$, where d is the depth of the cut, together with three to five pointed lobes on each side; each lobe is itself a blade that leaves the midrib at 38°–58° toward the tip and reaches the envelope. Body and lobes are filled as one shape, under the nonzero rule, so there is no seam. One half of the leaf is multiplied darker, as if it were folded along its rib; then come the blotches, the pooled edge, and a white midrib with a white vein along every lobe.

Construction 3.7 (Sprays)**.** A *cyme*, the inflorescence of the forget-me-not, is a stem whose heading turns by $\pm\tau(s/L)^{2.3}$ at arc length s, with $\tau\in[170°, 270°]$: straight at first, it curls like a scorpion's tail at the end. Eleven to seventeen florets crowd along it, shrinking into buds toward the curl, and a second, shorter curl forks off it three times in five. A *sprig* is a stem that forks two or three ways four times, each fork 0.58 to 0.74 the length of its parent, with florets and buds at the tips. An *umbel* fans nine to thirteen rays over 110°, each ending in a small umbel of starry florets.

3.2.1 Composition

The garden is a plant, not an arrangement. It grows from one root in the bottom-left corner of the page, where the base of the stems curls into a scroll. Three stems run up the column through hand-picked control points, interpolated by Catmull-Rom splines and jittered by a millimeter or so on each page: the tallest ends in the large flower at the top, one in a lily, one in a flower half-way up. A fourth stem leaves the root along the bottom of the page, carrying small leaves that thin out toward its

2

8.4 Writing a theme

A theme returns its primitives by name, with the same arguments and frame as the ones they replace (`flower(rng, s)` centered on its origin, `sprig(rng, L)` from its base along +y, `leaf(rng, o)` one unit long along +y, scaled by its caller, ...), and a function that may reweight the motif rows and add new ones:

```
-- florilegium-theme-<name>.lua
return {
  flora = { flower = function(rng, s) ... end, leaf = function(rng, o) ... end },
  motifs = function(rows, F) ... return rows end,
}
```

A theme with `page = function(g, grow)` gets the whole page instead and lays it out itself, as `florilegium-theme-math.lua` and `florilegium-theme-shells.lua` do.

`florilegium-theme-geometric.lua` is the example to start from, and CLAUDE.md lists the rules a theme has to keep (the animation's, mirrored pages', density's).

9 How it works

All geometry is computed in Lua while LuaLaTeX ships the page out, and written into the page as PDF path operators. TeX does no arithmetic, and nothing is an image: every petal, leaf and stem is a curve computed from the page's seed. The files are listed in CLAUDE.md, which maps the code in more detail.

9.1 Painting

`florilegium-ink.lua` is the drawing core. Primitives are drawn in a local frame under an affine transform, which is read from TikZ when a primitive is called inside a scope. Colors come from a tone ramp derived from the one document color `ink`, from navy to mist at the hue of `ink`, interpolated in OKLCH so the light end stays blue instead of turning gray. Tapered strokes are two offset Béziers, not sampled ribbons. Washes are translucent and multiplied, like pigment laid over pigment.

Everything is painted in the order a watercolorist would use: a flat wash, darker blotches multiplied over it, pigment pooling at the edges, streaks lifted out in white, a few fine veins, and almost no outlines. v1.3's primitives (`florilegium-flora.lua`) are broad petals and flowers, star lilies seen at a tilt, blossoms and florets, buds and bellflowers; lobed and entire leaves; forget-me-not cymes that curl like a scorpion's tail, branching sprigs, umbels, tendrils, seed heads; butterflies, bees, snails and a bird; copper sparkles, rosettes and the ivy-leaf fleuron whose stem becomes the head rule. Any of them can be painted as a pale ghost. The species' organs (`florilegium-native.lua`) are painted the same way (see the species garden).



300 dpi. Mottled washes with white streaks lifted out, leaves with white veins, a songbird on its twig, and a pale ghost lily behind the stems.

9.2 The grown margin

The grown composition (`florilegium-grow.lua`) follows Wong, Zongker and Salesin, *Computer-Generated Floral Ornament* (SIGGRAPH 1998).

The online documentation shows seed 6 growing, with the free discs marked as an animation.

Seed 6 growing. Each dashed circle is the largest free disc the loop found, just before a branch grows to it.

1. **Regions.** The garden may grow in the margin column, in a band along the bottom of the page, and on the last page in the space below the text.
2. **Stems.** Three stems rise from a root near the bottom corner, each swaying as smooth noise of its height, so they cross now and then. Each is one plant, a species of its own. The tallest ends in the hero's largest flower at the top of the page, the others stop at about two thirds and two fifths of it. A fourth stem runs along the bottom of the page as the footer.
3. **Leaves** hang at the nodes, as the species sets them (alternate, opposite, whorled), only where there is room.

4. **Free space.** A grid of points 2 mm apart keeps, for each point, the radius of the largest free disc around it and its distance to the nearest stem. Every motif placed is a disc too, counted at 85% of its radius so that a leaf can tuck under the edge of a flower.

5. **The loop.** Take the largest free disc within 3 cm of a stem (with a random factor, so ties break differently on every seed), choose a motif of the plant whose stem is nearest that fits it, scale it to the hole, and grow a branch to it from that stem. The branch leaves its stem along the stem's own direction and arrives along the motif's axis, so every flower can be traced back to the root, and it becomes a stem for later branches. Stop when no hole larger than 3.6 mm is left.

6. **Filling.** Holes of more than 1.7 mm next to a stem get buds, leaflets or small florets; a few far holes get a copper accent, and the rest stays paper.

Because the largest hole is always taken first, the big flowers land early, sprays and leaves fill the middle, and the loop ends by tucking small things onto the stems. That ordering is the whole reason the margin looks composed rather than scattered.

The end of the text is measured in the same run. `\florilegiumtextend` records how far down the page the text has gone, and that page's background is drawn after it. So a short last page grows arcs from the main stems into the space below the text, each ending in a flower, with one compilation.



The last page of `florilegium-grow.tex`*. The text ends near the top, and the garden grows into the rest of the page, down to the line of the page number.*

9.3 Reading the page

A heading or `\florilegiumbloom` leaves an invisible marker node in the text. When the page is shipped out, its box is walked node by node, adding up heights, depths and the glue as it was set, to find each marker's height on the page; the garden then gives those lines their flowers before any leaf is hung. An age reweights what grows and sets each flower's stage, from buds in spring to seed heads in autumn, when some leaves are painted with a ramp built from the accent instead of the ink.

9.4 The authored page

The authored composition (`florilegium-authored.lua`) is a score. A plant grows from a root in the bottom-left corner: three stems through hand-picked control points, a fourth along the bottom of the page as the footer, leaves at chosen fractions of the stems, and every other motif on a branch that leaves its stem tangentially and arrives along the motif's axis. Only the parameters are sampled. It keeps v1.3's hand-designed shapes.

9.5 Initials

`florilegium-initial.lua` reads the letter's outline from luaotfload's OpenType reader as Bézier segments. Flattened into polygons, it gives an even-odd inside test, and a grid of distances to the letter and the frame finds the largest gaps for the flowers. The vine is a Catmull–Rom curve across the tile; where it crosses the letter it goes over and under in turn, and the strands that go over are drawn again, clipped to the letter, with a thin halo of paper.

9.6 Watching it grow

The growth is recorded once, while the page is laid out: each stem is also drawn as prefixes of increasing length and each motif at a few smaller scales, replaying the same random draws. A frame then writes the pieces whose time has come, in their original painting order, and the last frame is exactly the page. `make grow-6` renders one seed this way (`build/grow-6.gif` and `.mp4`, about 45 seconds); add `EXPLAIN=1` for the dashed circles.

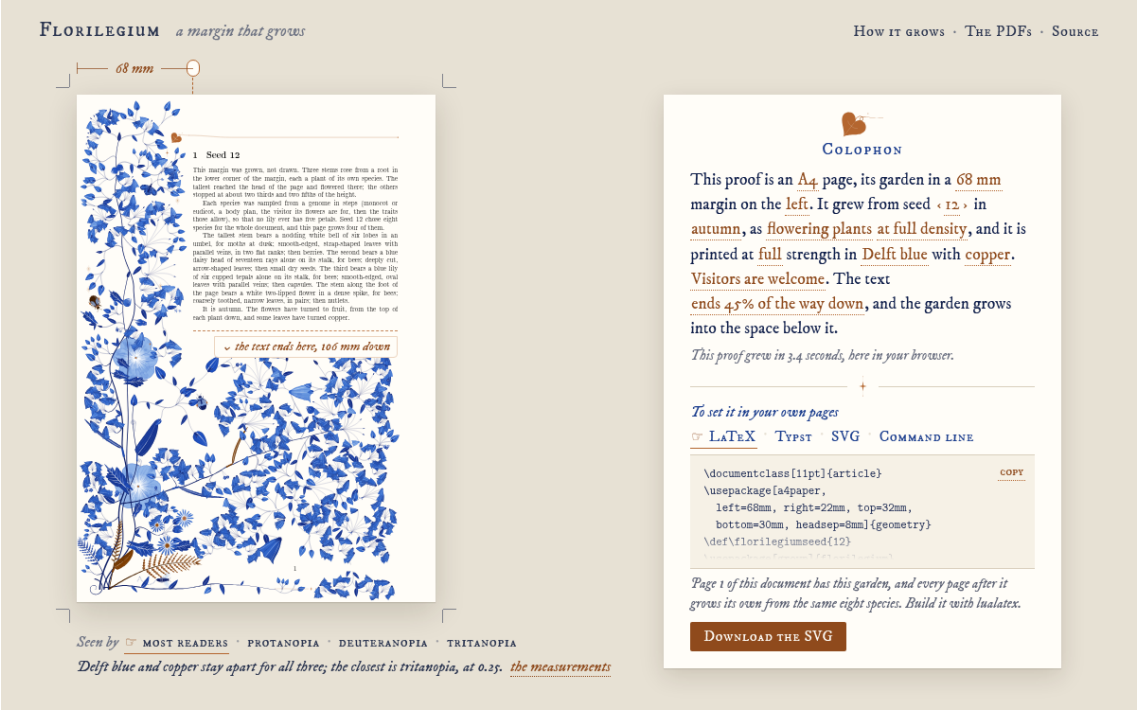
9.7 Procedural is not random

The seed comes from the page number, so page n always gets garden n, and every random choice draws from a stream that depends only on it. Visitors, the seasons' additions, the species and the fern each draw from a stream of their own, so none of them moves another's random choices. A page that no visitor came to is exactly the page `novisitors` draws, and where a visitor does come, it takes room the plants would have grown into. Reproducibility is what makes a document stable enough to typeset, and the same seed draws the same page byte for byte under LuaLaTeX, Lua 5.3, Lua 5.4 and the browser.

9.8 Size and time

A species page is about 5 MB of path operators, about 1 MB in the PDF, and adds about 1.2 seconds to a LuaLaTeX run; a v1.3 page about 3 MB, 0.6 MB and 0.7 seconds (time and PDF size from `make bench`, 2026-11-03, as in README's table). Output, not time, is the constraint, so coordinates are printed to a tenth of a point, a path used for a fill and a clip is written once, and small things are drawn with less detail (a petal under 1.2 mm has no mottle or pooled rim).

10 SVG, Typst and the browser



The playground, seed 12 in autumn on a last page. The page is a proof, and its colophon, the note a book keeps about its paper, ink and printing, is the set of controls: every copper word in it can be changed.

10.1 A page as SVG, without TeX

The same Lua can draw a page without TeX. `florilegium-svg.lua` runs the package's own code with a small stand-in for the few parts of TeX it touches (the page's lengths, the page number, and the node a drawing goes into), takes the PDF drawing commands that `florilegium-ink.lua` writes as it always does, and rewrites them as SVG. Nothing in the drawing code changes, so the garden is the one LuaLaTeX would draw, not an imitation of it.

```
texlua florilegium-svg.lua --seed 7 > margin.svg   # page 1 of a document with
↪  \def\florilegiumseed{7}
lua florilegium-svg.lua --seed 7 --season autumn --ink 5B2A1F --left 25mm --right 65mm
↪  > margin.svg
```

```
texlua florilegium-svg.lua --help                  # paper, margins, two-sided pages,
↪  the last page, themes...
make svg SEED=7                                    # -> build/svg-7.svg
```

A garden set on a page of its own, such as the part-title page of an e-book, does not end where the paper does. The reader's screen, its margins and its theme lie all around it, and the clip that keeps a printed margin inside the paper would cut the pale flowers along a straight line in the middle of the screen. `--bleed LEN` leaves the clip open along the paper's edges, so the garden may run up to LEN past them, and makes the SVG LEN larger on every side. The sides that face the text keep their clip, so the space for a title stays empty. It works for the grown page and the authored one; without it the SVG is the page LuaLaTeX draws.

```
lua florilegium-svg.lua --seed 3 --paper 120x200 --left 36mm --right 12mm --top 36mm
↪  --bottom 12mm \
  --headsep 0mm --headheight 0pt --textend 50mm --nohead --bleed 14mm > part-title.svg
```

Any Lua 5.3 or 5.4 runs it. Lengths are read the way TeX reads them and colors are converted the way xcolor converts them, so `--seed 7` with the default margins gives, byte for byte, the drawing on page 1 of `florilegium-grow.tex` built with seed 7. The SVG is a whole page with a transparent background, which makes it a page background anywhere.

This command line, and the same options given to the `page` function of `require( "florilegium-svg")` as a table, are what other tools should build on. They stay put from one release to the next, while the other files may be renamed or rewritten.

10.2 In Typst

```
#set page(paper: "a4", margin: (left: 68mm, right: 22mm, top: 32mm, bottom: 30mm),
  background: image("margin.svg", width: 100%, height: 100%))
```

10.3 The playground

The playground runs the same files in the browser with wasmoon, Lua 5.4 compiled to WebAssembly, in a background worker; a species page grows in a few seconds. Seed 7 there is seed 7 here.

The proof is the control surface as much as the colophon is: the measure above it sets the margin, and dragging the foot of the text up makes a last page. The text on the proof describes the garden that just grew, each plant in its own sentence and each visitor with what it did. Under it, the page can be seen as readers with protanopia, deuteranopia or tritanopia see it, with the distance between the ink and the accent measured for each (the model of Machado, Oliveira and Fernandes, distances in Oklab); a pairing that is hard to tell apart is flagged when you choose it. Next to the download are the LaTeX preamble, the Typst setup and the command line that make the same garden, and the address bar keeps every setting, so a garden can be shared as a link.

To run it from a clone, serve the repository with `make playground` and open `http://localhost:8000/web/`. The math and shells themes work too. The math theme's figures come from the same Lua; its equations and symbols, which TeX sets in a PDF, are set in

the playground by MathJax in the same Computer Modern, and the command line leaves them out. The fonts are served with the page (IM FELL DW Pica, and Latin Modern renamed as its license asks), so nothing is fetched from a font service.

11 Building and checking

The documents need LuaLaTeX, one run each, about a second a page (two runs for `showcase.tex`, whose seasons need the page count). The TikZ specimen sheet builds under pdfLaTeX too.

```
make                        # the four PDFs and the manual, florilegium-doc.pdf
make zip                    # build/florilegium.zip, the package as one folder
↪  (tools/zip.py says what goes in)
make seed-7                 # one page from seed 7 -> build/seed-7.pdf
make preview                # the gallery's preview images
make gallery                # gallery/seeds.png + seeds.gif, inks.png, seasons.png,
↪  themes.png, dials.png (python3, Pillow, pdftoppm)
make grow-6                 # growth animation of seed 6 -> build/grow-6.gif + .mp4
↪  (ffmpeg)
make grow-6 EXPLAIN=1       # the same with the free discs marked ->
↪  build/grow-6-explain.*
make svg SEED=7             # the same page as SVG, without TeX -> build/svg-7.svg
make social                 # the GitHub social image -> gallery/social.png (pdftoppm,
↪  Pillow)
make playground             # the browser playground at http://localhost:8000/web/
make postscript             # the PostScript port through Ghostscript ->
↪  build/postscript-7.pdf
make bench                  # v1.3 against this tree, and the TikZ library's engines
↪  (about 5 minutes)
lualatex specimen-tikz.tex                          # every species form, the Lua engine
↪  (seconds)
extra_mem_top=20000000 pdflatex specimen-tikz.tex  # the same in pure TikZ (about 10
↪  minutes)
sh tools/tikzcheck-ci.sh [plants]                   # what CI's tikz jobs run, one
↪  family (plants fern visitors tracery shells) or all, on every core
```

No TeX installed? Build the image once and run everything in it:

```
docker build -t florilegium-tex tools
make RUN=tools/in-docker
```

11.1 Checks

These are the checks CI runs, or that a change to one part calls for. Each is described at the top of its file. After a change that is meant to move a drawing, `tools/in-docker l3build save <test>` records that test again; look at its pages before committing the new log.

```
make luacheck RUN=tools/in-docker                    # luacheck over every Lua file
↪  (.luacheckrc)
make check RUN=tools/in-docker                       # l3build's regression tests,
↪  every drawing on their pages by its md5 (~10 s)
make check-tagging                                   # the tags of a tagged document,
↪  in CI's newer TeX Live image (TAGGING=save saves the list of tags again)
```

```
tools/svgcheck.sh lua5.3 lua5.4                        # varied pages through
↪  florilegium-svg.lua, byte-identical across interpreters
tools/in-docker texlua tools/speciescheck.lua 2000     # sampled species and visitors
↪  keep every rule; the TikZ tables and docs/traits.md are current
tools/in-docker texlua tools/tikzcheck.lua 1 1000      # TikZ and Lua sample the same
↪  species (v:any for visitors, t:any for windows of tracery)
tools/in-docker texlua tools/tikzcheck.lua draw quick # the Lua engine's pics render as
↪  pure TikZ's (about 15 minutes; draw plants, fern, visitors, tracery or shells for
↪  one family)
tools/in-docker texlua tools/pgfmathcheck.lua 30000    # the pgfmath arithmetic Lua
↪  takes from TeX, exactly
tools/in-docker texlua tools/animcheck.lua 1 2 3       # the last frame of the animation
↪  is the page
tools/in-docker texlua tools/ident.lua build/ident-a   # content streams to diff before
↪  and after a change
tools/versioncheck.sh                                  # every file names the same
↪  release
tools/sri.sh                                           # the playground's pinned CDN
↪  files still match their hashes
make pscheck                                           # the PostScript port against its
↪  recorded checksums
```

The playground has its own check, which operates every control in a headless browser. Serve the repository (`make playground`), then run `cd tools/playcheck && npm install && node check.mjs http://localhost:8000/web/ ../../build`. `node shot.mjs` in the same folder takes the README's screenshot of the playground.

12 Credits and license

12.1 Credits

- The Reddit post that asked the question (see Origin).
- The growth loop follows Wong, Zongker & Salesin, *Computer-Generated Floral Ornament* (SIGGRAPH 1998).
- The tone ramp is computed in Oklab, Björn Ottosson's perceptual color space; the conversion matrices in `florilegium-ink.lua` are his, released into the public domain (or under the MIT license, for those who prefer it).
- Most random numbers come from mulberry32, Tommy Ettinger's generator, dedicated to the public domain (CC0); a species is sampled and drawn with pgf's generator instead, replayed in Lua (see the TikZ library below). The PostScript port uses the "minimal standard" generator of Park and Miller (Communications of the ACM, 1988) by Schrage's method (ACM Transactions on Mathematical Software, 1979).
- The ivy-leaf fleuron (`hedera`) is outlined by the parametric heart curve $x = 16 \sin^3 t$, $y = 13 \cos t - 5 \cos 2t - 2 \cos 3t - \cos 4t$, the first one in Eric W. Weisstein's *Heart Curve* (Wolfram MathWorld), which names no author for it.
- The species' trait tables follow research notes made for this project. Only a radially symmetric flower varies its number of petals, as Damerval and Nadot found in the buttercup order (Annals of Botany, 2007). Flowers and visitors are paired by the pollination syndromes of the U.S. Forest Service's *Pollinator Syndromes* page. Heads

and daisy discs are packed on Helmut Vogel's model of the sunflower (Mathematical Biosciences, 1979), and a butterfly's pattern follows the nymphalid groundplan of Schwanwitsch (1924) and Süffert (1927). A snail's shell and every coiled shell is Raup's coiled tube (Journal of Paleontology, 1966), its ring placed as Okabe and Yoshimura reparameterize it (Scientific Reports, 2017), and its whorls touch where W times D is at most 1, as McGhee states it (Interface Focus, 2015).

- The tracery's periods are Thomas Rickman's names (*An Attempt to Discriminate the Styles of English Architecture*, 1817), and its cusped heads and foiled circles follow Sven Havemann and Dieter W. Fellner, *Generative Parametric Design of Gothic Window Tracery* (VAST 2004).

- The TikZ library draws with PGF/TikZ (Till Tantau and others; LPPL 1.3c or GPL 2), and its random numbers and arithmetic are pgfmath's, by Mark Wibrow, whose ln follows an algorithm due to Rouben Rostamian with coefficients by Alain Matthes. `florilegium-pgfmath.lua` reimplements the part the species need in Lua (pgf's generator; pgfmath's reading and printing of numbers, its multiply, divide, ln, exp and pow). It is not part of pgf; its header says how it differs and where pgf is, as the LPPL asks of a derived work, and like pgf it is under the LPPL 1.3c.

- `--bleed` in `florilegium-svg.lua` comes from jfoboss's e-book port, whose unclip step it does. jfoboss proposed it for this repository in #27, whose test page and part-title example are in 2.0.

- The repository's social image writes "florilegium" along the strokes of the Hershey Script Simplex font, which Dr. A. V. Hershey made at the U.S. National Bureau of Standards; its data format is James Hurt's (Cognition, Inc.). `tools/hershey/README.md` gives the font data's source and terms.

- `\florilegiumornament`, its `ink` and `seed=random` keys, and the `density` option answer issue #4 from rubyFeedback.

- The playground runs the Lua in the browser with wasmoon (MIT) and typesets the math theme's equations with MathJax (Apache 2.0), both loaded from jsDelivr. It is set in Igino Marini's IM FELL DW Pica (SIL OFL) and Latin Modern (GUST e-foundry, GUST Font License); see `web/fonts/README.md`. Its color-blindness views use the model of Machado, Oliveira & Fernandes, *A Physiologically-based Model for Simulation of Color Vision Deficiency* (IEEE TVCG, 2009).

- The math theme's figures keep the names of the people they come from: Maurer's roses, Vogel's model of the sunflower, Temple Fay's butterfly curve, the Petersen graph, Koch's snowflake, Hilbert's curve, Lissajous figures, the gasket of Apollonius.

12.2 License

MIT, see LICENSE, except `florilegium-pgfmath.lua`, which reimplements part of pgf in Lua and is distributed under the LaTeX Project Public License 1.3c, as its header says. Copyright (c) 2026 Kevin Raymond.