

# Julia for Beginners

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In our previous article, [What Is Julia, and Why It Matters?](#), we discussed why Julia is so relevant today and made some comparisons between other similar languages, such as Python and R. We also mentioned some of its main characteristics and features, and concluded with some next steps to get started programming on Julia.

In this Blog Article, we'll install Julia and an awesome [VS Code](#) extension that will make programming easier for us. We'll also take a look at two notebook environments: [Pluto.jl](#), a great Julia-specific notebook environment, and [JupyterLab](#). We'll set up an environment, install some packages, and cover several practical examples, where we will perform a general overview of Julia's main functionalities. We will close this segment by recommending how to use Julia and some helpful next steps for those interested in this exciting, bleeding-edge programming language.

We'll be using Julia scripts and reactive notebooks, which can be found in the [Blog Article Repo](#). Datasets can also be found in the [datasets](#) repo folder.

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## What to expect

Although Julia is a relatively new language and doesn't enjoy the vast IDE support that Python has (*yet*), we have limited options, but the ones currently available are superb and well-maintained. This segment will heavily rely on VS Code since it's the IDE presently getting the most support. Some time ago, [Juno](#) was also well maintained, but efforts have now been transferred entirely to the VS Code extension. We will also use an extremely fun Julia-specific notebook environment called `Pluto.jl`, as well as the well-known JupyterLab. We

will be using Microsoft Windows, but a similar installation process applies to other platforms, such as macOS & Linux. The rest of the article can be easily translated for other platforms.

Also, we'll assume there is at least some knowledge or background in some programming language since Julia, despite being syntactically simple, can get complex quickly; Python should do just fine since they're very similar syntax-wise.

We will not rigorously explore all of Julia's functionalities since there is too much to cover. Instead, we will review a comprehensive set of hands-on examples to start programming in Julia from scratch.

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# Installation

For this segment, we will need to install four main components:

- The Julia programming language.
- Visual Studio Code.
- The Visual Studio Code Julia extension.
- The JuliaMono typeface.

We will also install some packages, which will come later when we get to the `pkg` package manager.

## 1. Julia

We will first install the latest stable release of the Julia programming language. We can head to the official [Julia Lang website downloads page](#). We will select the *Windows 64-bit (installer)*. Once we have it, we'll run the executable and follow the shown steps.

Adding Julia to `PATH` is important since this will ensure we can start the Julia REPL directly from our terminal without specifying the whole absolute path for the executable. This will be useful when creating our project environment and installing some packages.

If we missed this step for some reason, that's perfectly fine. We can simply follow the steps below:

1. Open Windows Run by using `Windows Key + R`.
2. Type `rundll32 sysdm.cpl,EditEnvironmentVariables` and hit `Enter`.
3. Head to user variables.
4. Find the `Path` variable.
5. Click *Edit*, and then click *New*.
6. Depending on whether the installation was performed using administrator or user-wide permissions, we will need to find the Julia executable either in `C:\Program Files (x86)\Julia-1.8.3\bin`, or `C:\Users\ourusername\AppData\Local\Programs\Julia-1.8.5\bin`.
7. Copy the corresponding absolute path and paste it directly into the new `Path` entry.
8. Click *OK* twice.
9. make sure that Julia was added to `Path` by opening the Windows Terminal and typing `Julia`. If everything went smoothly, this command should open the Julia REPL. We can verify this by typing `VERSION` inside the REPL. This should return the version we installed.

## 2. VS Code

If we don't yet have VS Code installed, we can get it from the [official downloads page](#). We need to select the Windows 8, 10, 11 executable and wait for it to download. When the installation is complete, we can verify by

opening the Visual Studio Code application directly from the Windows start menu. A detailed configuration guide for VS Code is out of the scope of this article but can be consulted on the [VS Code official documentation site](#).

### 3. Julia VS Code extension

Once we have Julia and VS Code installed, we will proceed to install the Julia VS Code Extension:

1. Open VS code and head to the Extensions menu in the left panel. We can also open the Extensions menu by using the shortcut `Ctrl + Shift + X` or by opening the command palette by typing `F1` and searching for *Extensions: Install Extensions*.
2. We will search for Julia, maintained by *julialang*, install it, and enable it. We can also get the extension by using [this link](#).

Now that everything's in place, we're ready to start configuring our working environment.



## Configuring the JuliaMono Typeface

We mentioned the JuliaMono typeface in the last Julia article because it fits perfectly with Julia's scientific philosophy and syntactic style. We will install the font family and make ligature adjustments to have exactly what we want.

To begin, we will head to the [official JuliaMono Typeface website](#). There, we will see all the documentation available for this package. Now that we know more about this awesome font family, we will need to follow the steps below:

1. Download the font by heading to the [cormullion/juliamono](#) repository.
2. Look for the `juliamono-ttf.zip` file and download it.
3. Extract the `.zip` file contents.
4. Open the Fonts menu by using `Windows Key + R`, and typing fonts.
5. Select and drag all the extracted `.ttf` files to the *Fonts* folder and wait for the installation to conclude.
6. Once we have the fonts installed, we will head to VS Code, open the command palette with `R`, and look for *Preferences: Open Settings (UI)*.
7. We will then search for the *Font Family* option, and locate the *Editor: Font Family* setting.
8. We will change whichever font we had previously designated for `JuliaMono` (*no spaces in between*).
9. We will then close the settings and open the VS Code command palette again. We will now search for *Preferences: Open User Preferences (JSON)*
10. We will be presented with a JSON file which handles user-wide VS Code configuration parameters.

Depending if we have already configured something beforehand, we will be presented with different settings. We will need to add an additional JSON entry called `editor.fontLigatures`. Font ligatures are glyphs that combine the shapes of specific sequences of characters into a new form that makes for a more harmonious reading experience. A typical example is the *fi* ligature, which combines a lowercase *f* and a lowercase *i* into a single glyph so that the shoulder of the *f* doesn't clash with the dot of the *i*.

The JuliaMono typeface has a selection of ligatures we can choose to enable or not, depending on our specific taste. For the complete set of ligatures, we can head to [cormullion's blog](#). There, we will be presented with all the options we can add, along with some examples.

We will have to select the ligature codes we're interested in and set them in the user configuration file we previously opened:

## CODE

```
"editor.fontLigatures": "'zero', 'ss01', 'ss02', 'ss03', 'ss04', 'ss05', 'ss06', 'ss07', 'ss08',  
'ss11', 'ss12', 'ss13', 'ss14', 'ss15', 'ss20'"
```

We can now save our JSON file and close it.



# The Julia REPL

The Julia REPL (*Read-Eval-Print-Loop*) is Julia's shell, which we'll use extensively to configure our environment and download packages.

We can access the REPL using two methods:

- By calling it from PowerShell
- By using it from within VS Code (*we'll review this later on*)

To open it from PowerShell, we can type Julia:

## CODE

```
julia
```

We will be presented with the Julia logo, as well as the version we're using and some additional documentation information:

## OUTPUT

```
      _
     _(_) _ | Documentation: https://docs.julialang.org
  ( )  | ( ) ( ) |
   _ _ _| | _ _ | Type "?" for help, "]"? for Pkg help.
 | | | | | | / _ | |
 | | | | | | ( | | Version 1.8.3 (2022-11-14)
 _/ | \ _ ' | | | \ _ ' | Official https://julialang.org/ release
 | _/ |
```

We can exit the Julia REPL by typing `exit()` .



# Creating a Working Environment from the REPL

The first thing we'll do before we install our packages is set up a working environment (*similar to a Python virtual environment*). For this, we will head to our working folder:

## CODE

```
cd computer-science/julia-for-beginners
```

We will then access the Julia REPL and use the right bracket `]` to access Julia's `pkg` package manager. This will change the prompt and tell us which Julia version we're currently using:

```
(@v1.8) pkg> | Documentation: https://docs.julialang.org  
|  
| Type "?" for help, "]"? for Pkg help.  
|  
| Version 1.8.3 (2022-11-14)  
| Official https://julialang.org/ release  
|  
|
```

FIGURE 1: JULIA  $P_{\text{KG}}$  PROMPT FROM THE REPL

We will then type `generate` followed by our `project_name`:

## CODE

```
generate project_name
```

## OUTPUT

```
Generating project julia_project:
  julia_for_beginners\Project.toml
  julia_for_beginners\src\julia_project.jl
```

This will create our environment folder containing two files:

- `Project.toml` will contain the environment `name`, the environment `UUID`, the `author`, and the project version (*not to be confused with the Julia version we're using*)
- `julia_for_beginners.jl` will be our main project file (*Julia files have the `.jl` extension*). If we open our file, we can see that we have some information already there:

## OUTPUT

```
module julia_project
greet() = print("Hello World!")
end # module julia_project
```

We can then head back to VS Code, select *File, Open Folder*, and choose our environment folder. We can ensure we're using the right environment by opening the VS Code command palette and selecting the *Julia:*

*Change Current Environment* option. This will display all the Julia environments we have currently set up. We can select the environment name we just created, and it will automatically be set as default for this folder (*if it has not already done so*).

We can make a simple test by opening our `julia_project.jl` file, deleting the existing contents, typing some code, and executing it:

## CODE

```
println("This is our first Julia Project!!")
```

## OUTPUT

```
This is our first Julia Project!!
```

We can then proceed to install some useful packages.

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# Installing packages using pkg from the REPL

Julia uses its own package manager called `pkg`. It's installed by default on all Julia releases.

We may notice that once we're inside `pkg` and inside our project folder, the environment is not active by default (*the left prompt will display our current environment*). Before installing our packages, we must activate our environment; otherwise, the packages will be installed in the global environment rather than in the one we just created. For this, we will type the following inside `pkg`:

## CODE

```
activate .
```

## OUTPUT

```
Activating new project at `C:\Users\username\Documents\computer-science\julia-for-beginners`
```

We are now inside our environment and ready to start installing the packages we'll use throughout this segment.

Installing packages in Julia is extremely simple. There are two main ways we can follow:

- We can directly use the `pkg` package manager from the Julia REPL by typing the right bracket `]` symbol. We can then install a package:

## CODE

```
add package_name
```

- We can also call `Pkg` from within a Julia script or the Julia REPL without having to enter `Pkg` :

## CODE

```
using Pkg  
Pkg.add("Package Name")
```

Note that for the first option, we don't enclose our `package_name` in quotes, while with the second approach, we do need to enclose the package name in quotes.

Let us now install the `DataFrames` package directly from `Pkg` inside the Julia REPL.

## CODE

```
add DataFrames
```

## OUTPUT

```
Precompiling project...  
 9 dependencies successfully precompiled in 37 seconds. 18 already precompiled.
```

Once we install our first package, a new file named `Manifest.toml` will be created. This file is important since it will contain all the currently installed packages, their dependencies, UUIDs and versions.

To install multiple packages at once, we can use a Julia script which calls `Pkg` and installs the required packages. We'll create a new `packages.jl` file inside our environment. We will then include the following and run it:

## CODE

```
pkgs = ["DataFrames", "Plots", "CSV", "Pluto", "PlutoUI", "IJulia", "TypeTree"]  
  
using Pkg  
  
Pkg.add(pkgs)
```

The following packages will be installed:

- `DataFrames`
- `Plots`
- `CSV`
- `Pluto`
- `PlutoUI`
- `IJulia`
- `TypeTree`



This will take some time since Julia first needs to download the packages if we still don't have them in our local machine and then precompile them.

In the end, we should get a similar output as the one below:

## OUTPUT

```
66 dependencies successfully precompiled in 235 seconds. 396 already precompiled.
```

We can test that our required packages were installed by closing the `packages.jl` script, going back to our `julia_project.jl` file, and loading a couple of random packages by using the `using` command. This imports our required packages and makes them available for our session:

## CODE

```
using DataFrames
using Plots

# Test libraries
x = range(0, 10, length=100)
y = sin.(x)
plot(x, y)

z = round.(y, digits=4)

print(z)
```

Alternatively, we can also import our packages using commas `,`:

## CODE

```
using DataFrames, Plots

# Test libraries
x = range(0, 10, length=100)
y = sin.(x)
plot(x, y)

z = round.(y, digits=4)

print(z)
```

If everything goes well, the plot should appear on a new window. It can also be accessed by heading to the Julia Extension menu in the left panel and expanding the *PLOT NAVIGATOR* menu. We should have our first plot figure, `plot_01`. We can click on it, and it will display.

## OUTPUT

```
[0.0, 0.1008, 0.2006, 0.2984, 0.3931, 0.4839, 0.5696, 0.6496, 0.723, 0.7889, 0.8469, 0.8962,
0.9364, 0.967, 0.9878, 0.9985, 0.999, 0.9893, 0.9696, 0.9399, 0.9007, 0.8523, 0.7952, 0.73,
0.6574, 0.5781, 0.4928, 0.4026, 0.3082, 0.2107, 0.1111, 0.0103, -0.0906, -0.1906, -0.2886,
-0.3837, -0.4748, -0.5612, -0.6418, -0.7158, -0.7826, -0.8414, -0.8916, -0.9327, -0.9643,
-0.9861, -0.9978, -0.9994, -0.9908, -0.972, -0.9434, -0.9051, -0.8576, -0.8014, -0.737, -0.6651,
-0.5864, -0.5017, -0.412, -0.318, -0.2207, -0.1213, -0.0206, 0.0804, 0.1805, 0.2787, 0.3742,
0.4658, 0.5526, 0.6338, 0.7086, 0.7761, 0.8358, 0.8869, 0.9289, 0.9615, 0.9843, 0.9971, 0.9997,
0.9921, 0.9744, 0.9467, 0.9094, 0.8629, 0.8075, 0.7439, 0.6727, 0.5947, 0.5106, 0.4213, 0.3277,
0.2308, 0.1315, 0.0308, -0.0701, -0.1703, -0.2688, -0.3646, -0.4566, -0.544]
```

## OUTPUT

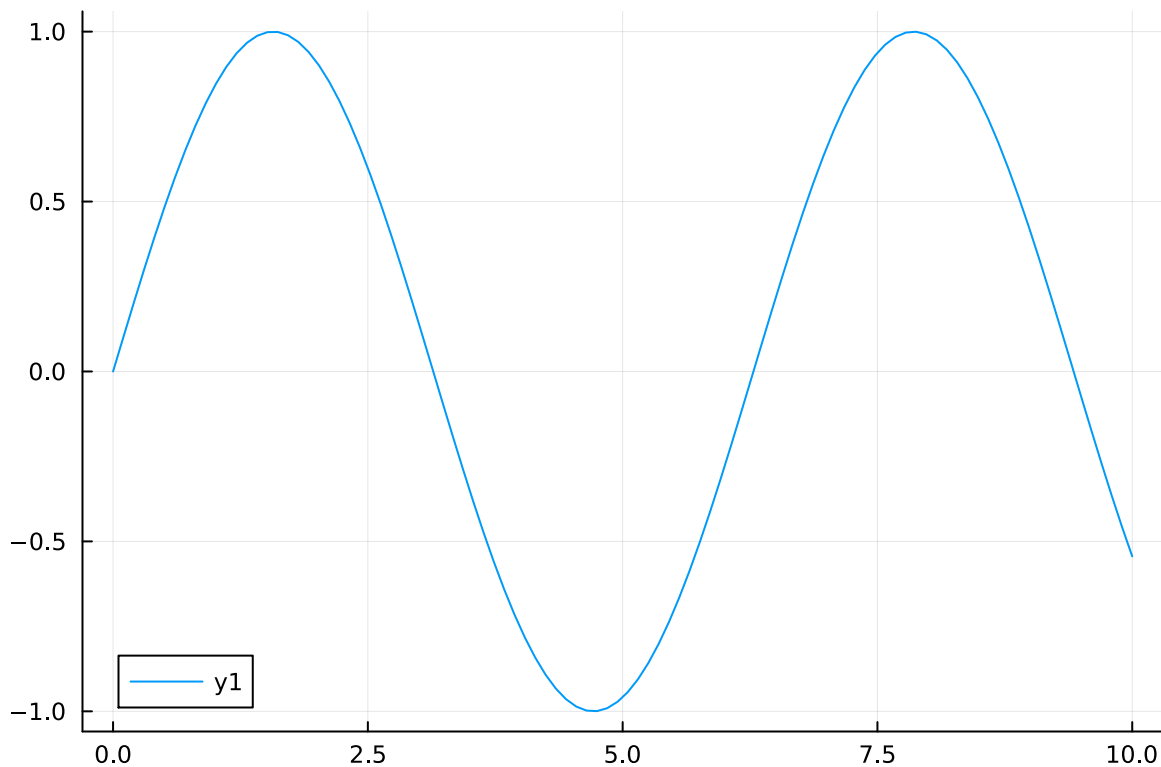


FIGURE 2: A SIMPLE PLOT CREATED USING THE `Plots` PACKAGE

To uninstall a package from our current environment, we can go to our environment's Julia REPL and type the following:

## CODE

```
using Pkg
Pkg.rm("Symbolics")
```

We can then confirm that our package has been removed, by opening our environment's `Project.toml` file:

## CODE

```
code .\Project.toml
```

We should not see the removed package nor its UUID referenced in the `[deps]` section.

If we are getting errors regarding unresolved dependencies, we can resolve them from our environment's Julia REPL:

## CODE

```
using Pkg
Pkg.resolve()
```

This command will rebuild our `Manifest.toml` file if a conflict is found.

When working with environments, the `instantiate` command is a handy tool. It will install all dependencies required for the project on `Manifest.toml`. In simpler terms, we can clone a Julia repository containing a `Manifest.toml` file and run this command; it will install all the packages required for the project.

We can execute this command directly from our environment's Julia REPL:

## CODE

```
using Pkg
Pkg.instantiate()
```

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# Getting familiar with the VS Code extension

Julia's VS Code extension offers multiple functionalities:

- Syntax highlighting
- Snippets: latex and user-shared snippets
- Julia specific commands
- Integrated Julia REPL
- Code completion
- Hover help
- A linter
- Code navigation
- Tasks for running tests, builds, benchmarks and build documentation
- A debugger
- A plot gallery
- A grid viewer for tabular data
- Integrated support for `Weave.jl`

The complete official documentation can be found [here](#).

# 1. Using the Julia REPL inside VS Code

We can open a Julia REPL that already has our active environment by opening the VS Code command palette and selecting *Julia: Start REPL*. We can also do this directly by using the `alt + j + o` (*Julia open*) key combination. We can confirm that we're using our current environment by entering into `pkg` using the right bracket `]`; our environment will display on the REPL prompt. This method knows which Julia environment to use by looking at the `Project.toml` & `Manifest.toml` files inside our current folder. If it finds none, it will default to the global Julia environment.

We can directly run a script in the current environment REPL by using the `ctrl + F5` key combination. To clear our REPL, we use the `ctrl + l` key combination. We can also directly input commands into the environment REPL, and they will run.

If we would like to run a single code selection, we can select the code we'd like to run and use the `ctrl + shift` key combination. This is very useful since we don't have to run the entire script, as previously defined variables will not get deleted upon execution.

We can also run a Julia script directly from our Windows terminal inside VS Code. The catch is that we will need to specify an additional `--project` parameter for the correct environment REPL to execute our script. Otherwise, the script will be executed by the global Julia environment:

## CODE

```
julia --project .\julia_project.jl
```

# 2. Workspace variables

We can view our workspace variables by heading to the Julia menu in the left panel, expanding the *WORKSPACE* tab, and expanding the *Julia REPL* tab. This tab will show us all the imported packages for the current session and all the defined variables.

Julia VS Code extension has a built-in variable visualizer similar to Spyder. We can access any object by clicking the table icon at the right of the variable we wish to visualize:

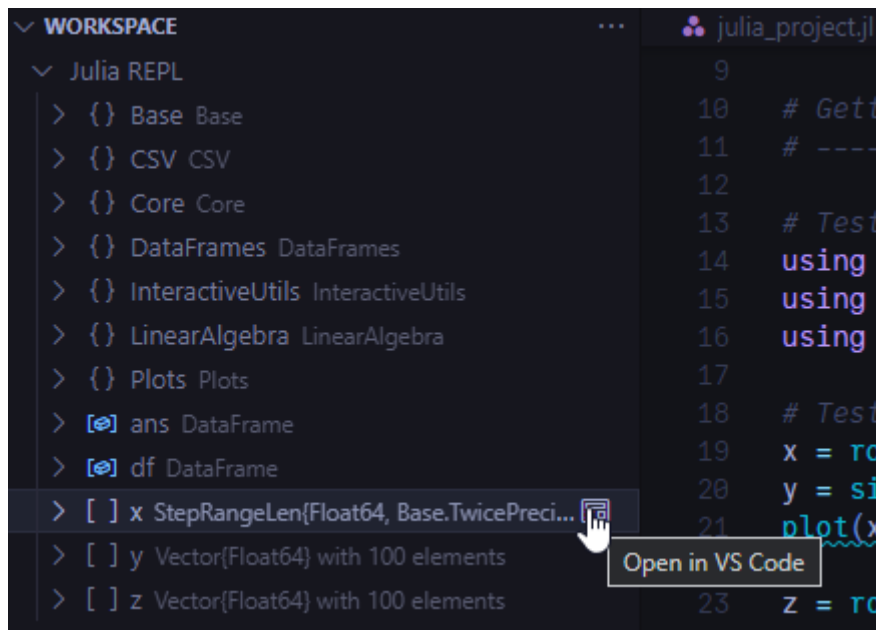


FIGURE 3: VISUALIZING A VARIABLE IN THE VS CODE OBJECT VIEWER

The beauty of this method is that it works for variables and tables.

To illustrate this, we'll create a very simple `.csv` file by heading to the *EXPLORER* tab on the left panel, clicking on *New Folder...*, and naming it `datasets`:

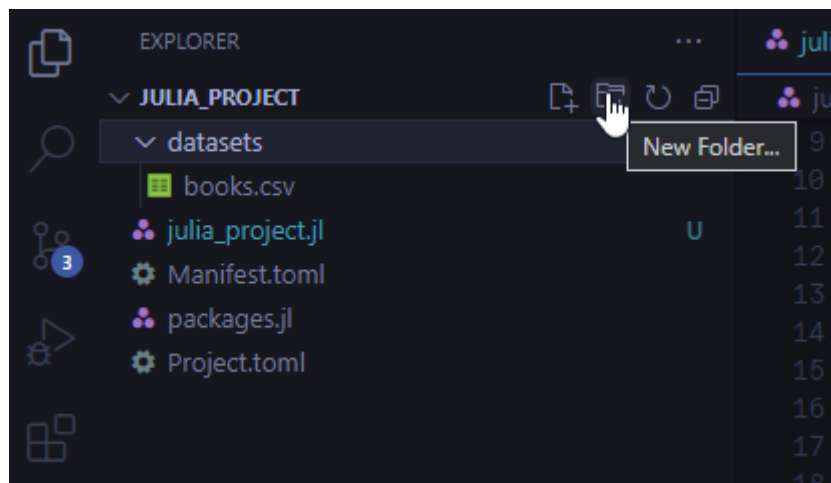


FIGURE 4: CREATING A NEW DATASETS FOLDER IN VS CODE

We'll then create a `.csv` file inside our `datasets` folder, and name it `test.csv`:

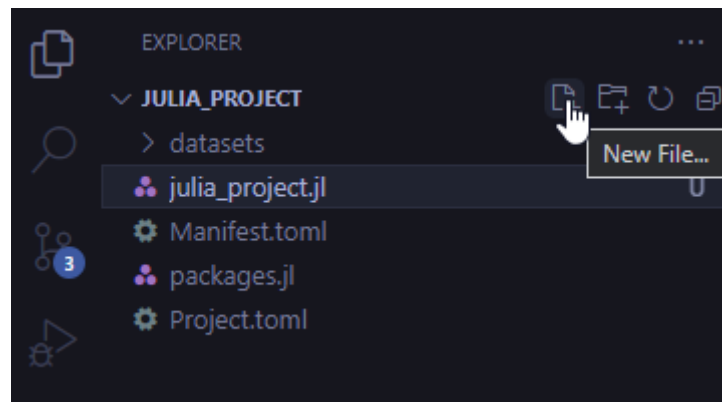


FIGURE 5: CREATING A NEW CSV FILE IN VS CODE

We will open this file and populate it with the following:

### CODE

```
Name, Age, Occupation
John, 34, Scientist
Mary, 25, Astronaut
Paul, 27, Writer
```

We will now read the CSV file into a DataFrame object. We already have the two required packages installed, so we'll only need to import them to our current session:

### CODE

```
using CSV, DataFrames

df_1 = CSV.read("datasets/test.csv", DataFrame)
```

We can now head back to the Julia menu in the left panel, expand our *WORKSPACE* tab, and open our table in VS Code.

### OUTPUT

julia_project.jl U		Julia Table: df_1 X	
Row	Name	Age	Occupation
1	John	34	Scientist
2	Mary	25	Astronaut
3	Paul	27	Writer

FIGURE 6: TABLE VIEW IN VS CODE

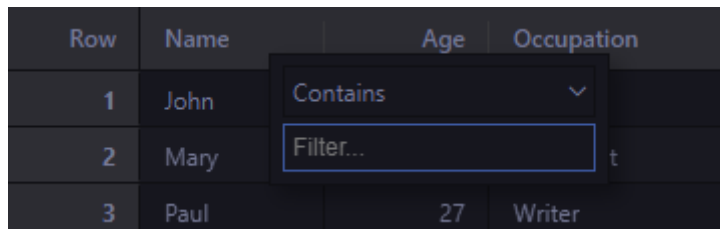
We can also display any figure in the VS Code viewer by using the following syntax inside our script:

## CODE

```
vscode.display(df_1)
```

Upon execution, this method will automatically open our table in a new tab.

This table view has some nice features we can take advantage of to visualize and explore a newly imported data set quickly. We can search, sort and filter by using the navigation buttons on each column header:



Row	Name	Age	Occupation
1	John		
2	Mary		t
3	Paul	27	Writer

FIGURE 7: SEARCH, SORT & FILTER USING THE TABLE VIEW IN VS CODE

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# Getting familiar with JupyterLab

As mentioned earlier, Julia supports two primary notebook environments: JupyterLab & `Pluto.jl`. JupyterLab is very popular among Data Scientists & Data Analysts and supports various languages.

If we recall the package installation segment above, we already added a package named `IJulia` to our environment. This package provides a Julia kernel for JupyterLab.

To launch a new JupyterLab session, we can open a new PowerShell instance, head to our working folder and open a new JupyterLab session:

## CODE

```
cd \julia_project  
  
jupyter-lab
```

## OUTPUT

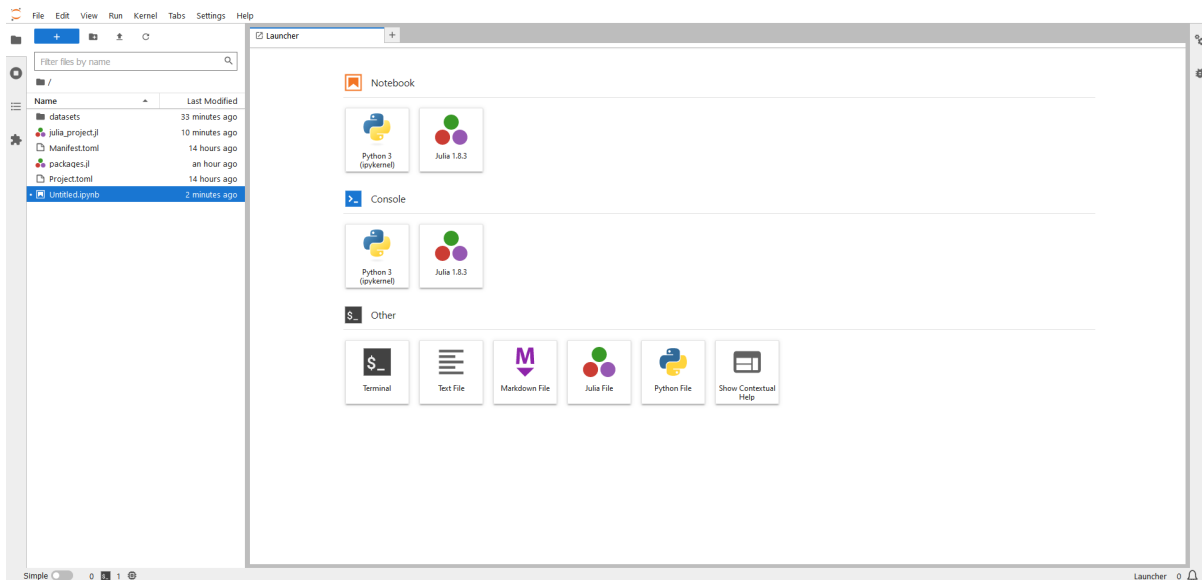


FIGURE 8: JUPYTERLAB SESSION

We can create a new Julia notebook, rename it as `julia_project.ipynb` and confirm that we started this session under our target working environment by importing a package we already installed:

## CODE

```
using CSV
```

A detailed guide on using JupyterLab is out of the scope of this article. Still, the [official documentation](#) is extremely helpful for those looking to dive deeper into this awesome notebook environment.

Once our session and notebook are ready, we can practically use them as we would with any other programming language.

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# Getting familiar with Pluto.jl

The other notebook environment we will discuss in this article is `Pluto.jl`. It's Julia-specific, extremely fun to use, has a minimal interface, and shares many similarities with JupyterLab.

`Pluto` can be installed using `pkg`. We can also complement our installation by getting the `PlutoUI` package; it will provide some additional `html"<input>"` functionalities. Since we already did this, we can head to our environment's Julia REPL, and import the `Pluto` package:

## CODE

```
using Pluto
```

We will then run the package:



## CODE

```
Pluto.run()
```

Upon execution, a new `Pluto` session will be created and launched in our system's default browser:

## OUTPUT

```
[ Info: Loading...  
[ Info: Listening on: 127.0.0.1:1234, thread id: 1  
└ Info:  
└ Opening http://localhost:1234/?secret=t6tEXgJ3 in your default browser... ~ have fun!  
└ Info:  
└ Press Ctrl+C in this terminal to stop Pluto  
└
```

## OUTPUT

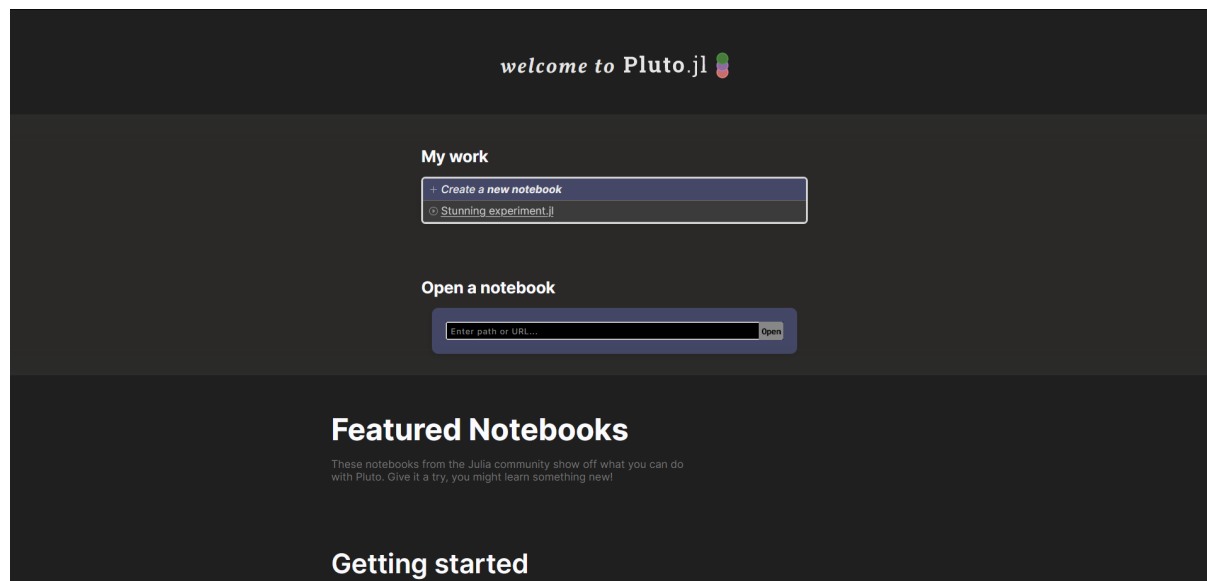


FIGURE 9: PLUTO SESSION

We will be presented with Pluto's main menu, where we will create a new notebook by selecting the *Create a new notebook* option. We will name it `julia_project_pluto.jl` (it's important to include the `.jl` extension).

As with JupyterLab, we will make sure we have installed `Pluto` in the correct environment:

## CODE

```
using PlutoUI
```

After this command, we will need to restart our Pluto instance since it will reload with additional UI features enabled.

We can display the Shortcuts menu using the `F1` shortcut. The relevant shortcuts we will use in this segment will be:

- `Shift + Enter`: Run cell
- `Ctrl + Enter`: Run cell and add cell below
- `Del` or `Backspace`: Delete empty cell
- `Ctrl + C`: Copy selected cells
- `Ctrl + X`: Cut selected cells
- `Ctrl + V`: Paste selected cells
- `Ctrl + M`: Toggle markdown

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# 1. Writing multiple lines on a single cell

Unlike with JupyterLab, if we try to write multiple lines of code in a single cell and execute, Pluto will complain:

## CODE

```
x = "Hello"
b = "World"
println(x, b)
```

## OUTPUT

```
Multiple expressions in one cell.
How would you like to fix it?
- [Split this cell into 3 cells](http://localhost:1234/edit?id=5cff5130-afd3-11ed-18db-8554d52bda68#), or
- [Wrap all code in a _begin ... end_ block.](http://localhost:1234/edit?id=5cff5130-afd3-11ed-18db-8554d52bda68#)

1. **top-level scope**@_none:1_
```

We need to wrap our code in a `begin` `end` statement:

## CODE

```
begin
  x = "Hello"
  b = "World"
  println(x, b)
end
```

## OUTPUT

```
HelloWorld
```

Conversely we can include each new line in a different cell:

## CODE

```
d = "Hello"
```

```
t = "World"
```

```
println(d, t)
```

## OUTPUT

```
HelloWorld
```

## 2. Inserting Markdown cells

As with JupyterLab, `Pluto` supports Markdown cells. To insert a Markdown cell, we can add a new cell and use the `ctrl + m` keyboard shortcut:

## CODE

```
md"""
#### This is a Markdown H4 header
- This is a list item
- This is a second list item

This is a LaTeX expression:
 $f(x)=x^2+x^3+x^4$ 
"""
```

## OUTPUT

THIS IS A MARKDOWN H4 HEADER

- This is a list item
- This is a second list item

This is a LaTeX expression:  $f(x) = x^2 + x^3 + x^4$

We can hide the actual Markdown code and keep the output by using the eye icon at the left of any Markdown cell:

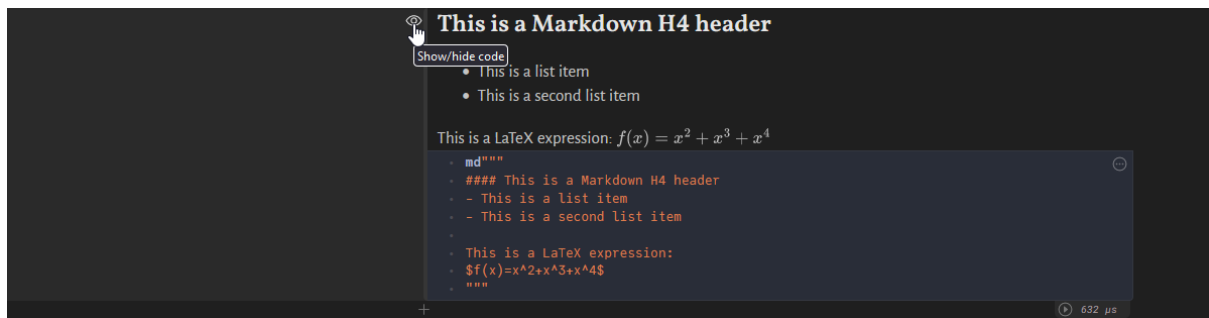


FIGURE 10: HIDING MARKDOWN CODE

### 3. Using PlutoUI

We mentioned that `PlutoUI` brings interesting UI functionalities to a `Pluto` notebook.

We can display all of `PlutoUI` methods:

#### CODE

```
varinfo(PlutoUI)
```

#### OUTPUT

name	size	summary
BuiltinsNotebook	356.538 KiB	Module
Button	144 bytes	DataType
CheckBox	144 bytes	DataType
Clock	184 bytes	DataType
ClockNotebook	280.173 KiB	Module
ColorPicker	40 bytes	UnionAll
ColorStringPicker	144 bytes	DataType
ConfirmNotebook	274.660 KiB	Module
CounterButton	144 bytes	DataType
DateField	160 bytes	DataType
DatePicker	160 bytes	DataType
DownloadButton	152 bytes	DataType
Dump	152 bytes	DataType
FilePicker	144 bytes	DataType
LabelButton	144 bytes	DataType
LocalResource	0 bytes	LocalResource (generic function with 1 method)
MultiCheckBox	80 bytes	UnionAll
MultiCheckBoxNotebook	280.652 KiB	Module
MultiSelect	80 bytes	UnionAll
NumberField	192 bytes	DataType
PasswordField	144 bytes	DataType
PlutoUI	650.302 KiB	Module
Print	0 bytes	Print (generic function with 1 method)
Radio	168 bytes	DataType
RangeSlider	240 bytes	DataType
RangeSliderNotebook	277.834 KiB	Module
RemoteResource	256 bytes	DataType
Resource	256 bytes	DataType
Scrubbable	248 bytes	DataType
ScrubbableNotebook	278.749 KiB	Module
Select	152 bytes	DataType
Show	80 bytes	UnionAll
Slider	40 bytes	UnionAll
TableOfContents	176 bytes	DataType
TableOfContentsNotebook	284.140 KiB	Module

name	size	summary
TerminalNotebook	283.801 KiB	Module
TextField	208 bytes	DataType
TimeField	160 bytes	DataType
TimePicker	0 bytes	TimePicker (generic function with 2 methods)
WebcamInput	200 bytes	DataType
WebcamInputNotebook	295.818 KiB	Module
WithIOContext	40 bytes	UnionAll
as_html	0 bytes	#4 (generic function with 1 method)
as_mime	0 bytes	as_mime (generic function with 2 methods)
as_png	0 bytes	#4 (generic function with 1 method)
as_svg	0 bytes	#4 (generic function with 1 method)
as_text	0 bytes	#4 (generic function with 1 method)
br	20 bytes	HTML{String}
confirm	0 bytes	confirm (generic function with 1 method)
with_terminal	0 bytes	with_terminal (generic function with 1 method)

TABLE 1: AVAILABLE PLUTOUI METHODS

### 3.1 Creating reactive buttons

We see that we have a `Button` method available. We can create a new button object and then assign a macro to it so that we can use it to interact with our notebook in multiple ways:

Let us define a button and bind it to a variable `my_var` :

#### CODE

```
@bind my_var Button("We Love Julia")
```

We can then define a code block which will contain our `my_var` variable, along with some actions to be executed:

#### CODE

```
data = let
  my_var
  f = rand(2)
  println("♥", round.(f, digits=4), "♥")
end
```

If we execute the code above for the first time, our variable will be instantiated:

#### OUTPUT

♥ [0.7841, 0.4072] ♥

We can now click on our defined button, and the cell will be referenced again, thereby running the code block we defined:

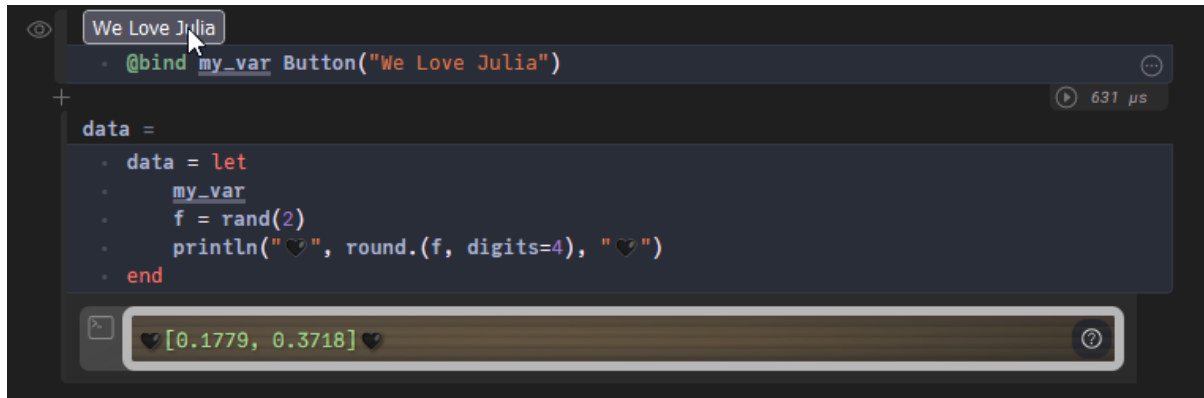


FIGURE 11: TOGGING A BUTTON CREATED USING PLUTOUI

We can see that a new pair of random numbers was generated.

We can also create `Radio` buttons, which can be assigned to a macro that reactively displays information depending on the option selected:

## CODE

```
@bind writer Radio(["William Shakespeare", "Alexandre Dumas", "Victor Hugo"])
```

```
println("Hi, I'm ", writer)
```

When we select William Shakespeare, he properly introduces himself:

## OUTPUT

Hi, I'm William Shakespeare

As we can imagine, there are many instances where these reactive objects could be useful. One such example would be flow control, where we could define breakpoints within a function. Another great application would be for debugging purposes, or we could also use buttons for dynamically displaying visuals.

---

## §

# Basic syntax

Now that we have some tools in our hands, we can start reviewing the basic Julia syntax. We will find many similarities with Python syntax; that's because Python is extremely easy to write, and Julia inherited a wide

range of syntactic elements from it.

For this section, we will create a new Pluto notebook and name it `basic_syntax.jl`.

# 1. Comments

As with Python, we can define single-line or multiline **comments**:

## CODE

```
# This is a single-line comment

#=
This is a multiline comment
=#
```

We can also define comments after a variable definition:

## CODE

```
my_var = 3.1416 # This is Pi
```

# 2. Variables

We can define **variables** by using the equal `=` sign:

## CODE

```
begin
    # Assigning integer
    x = 10

    # Assigning string types
    y = "Hello World"

    # Assigning float types
    z = -3.1416

    # Using a Unicode character as variable name
    λ = 30

    println(x)
    println(y)
    println(z)
    println(λ)
end
```

## OUTPUT



```
10
Hello World
-3.1416
30
```

We need to be careful when assigning variables; *e.g. if we define the `+` operator as a new variable, we will overwrite the actual `Base.:+` method and start getting all kinds of errors, additional to being extremely hard to debug.* We must remember reserved characters since Julia will not throw errors if we reassign them.

If we messed up and assigned a reserved name to a variable, we can reset it to its Base method:

## CODE

```
+ = Base.:+
```

If we recall, we can use Unicode characters as variable names in Julia. Of course, it's tedious to always refer to a Unicode character cheat sheet and copy and paste the required character. With Julia, we can simply use the backslash `\` character followed by the character name we're looking for and hit `TAB`. This will automatically insert the Unicode character:

## CODE

```
\lambda
```

## OUTPUT

```
λ
```

The character names are equivalent to LaTeX names, so if we're already familiar with LaTeX syntax, we should feel right at home.

If we're unsure about a specific character's name, we can start typing the name that would make more sense and then hit `TAB`. Pluto will display the entire list of available characters, where we can select the one we're looking for:

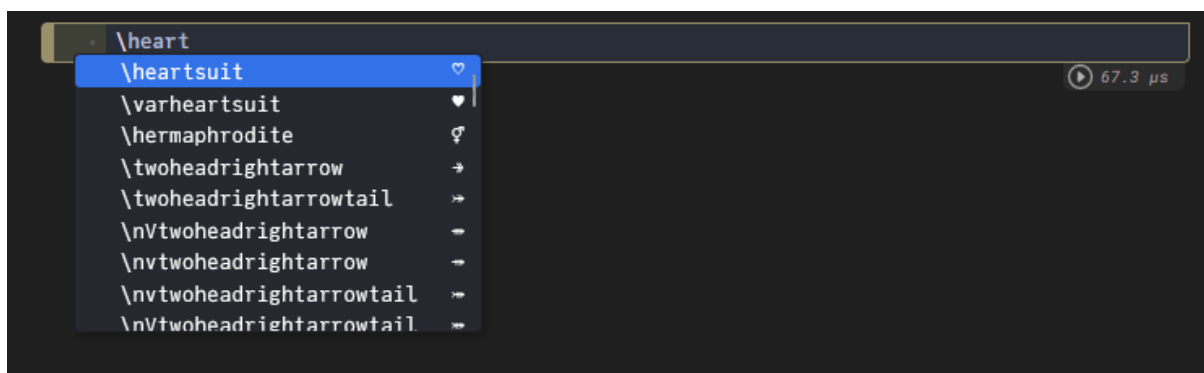


FIGURE 12: "HEART" UNICODE CHARACTER SUGGESTIONS PRESENTED BY PLUTO

We can also assign multiple variables using a single line:

## CODE

```
 $\gamma$ ,  $\theta$  = 300, 200
```

```
println( $\gamma$ , " + ",  $\theta$ )
```

## OUTPUT

```
300 + 200
```

# 3. Print statements

There are multiple methods we can use to **print** in Julia. The two most used are:

- `print`
- `println`

## 3.1 print

The `print` statement will print to `stdout` without a newline in between, even if we specify the statements in two separate lines of code:

## CODE

```
 $\pi$ ,  $e$  = 3.1416, 0.5772
```

```
begin  
    print( $\pi$ )  
    print( $e$ )  
end
```

## OUTPUT

```
3.14160.5772
```

## 3.2 println

In contrast, the `println` method (*print line*) will include a newline at the end of each call:

## CODE

```
begin
    println( $\pi$ )
    println( $e$ )
end
```

## OUTPUT

```
3.1416
0.5772
```

There are more printing methods available, but we're not going to dive deeper since the two we mentioned will suffice for almost any situation.

## 4. Data types

Julia's type system is **dynamic** but gains some of the advantages of static type systems by making it possible to indicate that certain values are of specific types.

Julia has a wide variety of types, which can be classified into supertypes or subtypes, depending on the hierarchy of our data type.

We can view Julia's `Signed` types in an ASCII tree-like structure by using the `TypeTree.jl` package:

## CODE

```
using TypeTree
```

```
print(join(tt(Signed), ""))
```

## OUTPUT

```
Signed
├─ BigInt
├─ Int128
├─ Int16
├─ Int32
├─ Int64
└─ Int8
```

We can go even higher in the tree structure and display all `Number` subtypes:

## CODE

```
print(join(tt(Number), ""))
```

## OUTPUT

```

Number
├─ Complex
├─ Real
│   ├── AbstractFloat
│   │   ├── BigFloat
│   │   ├── Float16
│   │   ├── Float32
│   │   └─ Float64
│   ├── AbstractIrrational
│   │   └─ Irrational
│   ├── Integer
│   │   ├── Bool
│   │   ├── Signed
│   │   │   ├── BigInt
│   │   │   ├── Int128
│   │   │   ├── Int16
│   │   │   ├── Int32
│   │   │   ├── Int64
│   │   │   └─ Int8
│   │   └─ Unsigned
│   │       ├── UInt128
│   │       ├── UInt16
│   │       ├── UInt32
│   │       ├── UInt64
│   │       └─ UInt8
│   └─ Rational

```

We can also display all the subtypes belonging to the `Any` supertype. We will truncate the output since there are too many entries to fit in one code block:

## CODE

```
print(join(tt(Any), ""))
```

## OUTPUT

```

Any
├─ AbstractArray
│  └─ AbstractRange
│     ├── LinRange
│     └─ OrdinalRange
│        └─ AbstractUnitRange
│           ├── Base.IdentityUnitRange
│           ├── Base.OneTo
│           ├── Base.Slice
│           └─ UnitRange
│              └─ StepRange
│                 └─ StepRangeLen
├─ Base.ExceptionStack
├─ Base.LogicalIndex
├─ Base.MethodList
├─ Base.ReinterpretArray
├─ Base.ReshapedArray
├─ Base.SCartesianIndices2
├─ BitArray
├─ CartesianIndices
├─ Core.Compiler.AbstractRange
│  ├── Core.Compiler.LinRange
│  ├── Core.Compiler.OrdinalRange
│  └─ Core.Compiler.AbstractUnitRange
...

```

There are multiple data types in Julia. We will only review the most used ones:

## 4.1 Integer types

Julia has a total of 10 integer subtypes, where 5 of them are signed, and 5 are unsigned:

Type	Signed?	Number of bits	Smallest value	Largest value
<code>Int8</code>	✓	8	$-2^7$	$2^7 - 1$
<code>UInt8</code>		8	0	$2^8 - 1$
<code>Int16</code>	✓	16	$-2^{15}$	$2^{15} - 1$
<code>UInt16</code>		16	0	$2^{16} - 1$
<code>Int32</code>	✓	32	$-2^{31}$	$2^{31} - 1$
<code>UInt32</code>		32	0	$2^{32} - 1$
<code>Int64</code>	✓	64	$-2^{63}$	$2^{63} - 1$
<code>UInt64</code>		64	0	$2^{64} - 1$
<code>Int128</code>	✓	128	$-2^{127}$	$2^{127} - 1$
<code>UInt128</code>		128	0	$2^{128} - 1$
<code>Bool</code>	N/A	8	<code>false</code> (0)	<code>true</code> (1)

TABLE 2: INTEGER TYPES, EXTRACTED FROM JULIA'S [OFFICIAL DOCUMENTATION](#)

We can define a variable and declare it as `Int32` type by using double colon `::` after the variable definition:

#### CODE

```
d::Int64 = 1000
```

We can verify the variable type by using the `typeof` method:

#### CODE

```
typeof(d)
```

#### OUTPUT

```
Int64
```

We can also test if our variable is of a specific type, by using the `isa` operator:

#### CODE

```
d isa Int64
```

#### OUTPUT

```
true
```

We can convert or promote an existing variable data type to a different type using the `convert` method if required. In this example, we convert from `Int64` to its unsigned version:

#### CODE

```
δ = convert{UInt64, d}
```

#### OUTPUT

```
δ = 0x000000000000003e8
```

## 4.2 Floating-point types

Julia has three different floating-point types depending on the maximum number of accepted bits:



## 4.4 String and Character types

### 4.4.1 STRING TYPES

String types are defined by enclosing the value in double quotes `""`:

#### CODE

```
σ = "This is the greek letter sigma"
```

Note that we mentioned double quotes `""` and not single quotes `' '`. This is because, unlike Python, single quotes are used to define **characters** and not strings. We'll discuss character objects in a moment.

#### CODE

```
typeof(σ)
```

#### OUTPUT

```
String
```

As with Python, we can index a string and return a substring:

#### CODE

```
σ[13:17]
```

#### OUTPUT

```
"greek"
```

We can also index a single element, but the returned object will be of a different type:

#### CODE

```
σ[1]
```

#### OUTPUT

```
'T': ASCII/Unicode U+0054 (category Lu: Letter, uppercase)
```

Instead of returning a String type, this operation returned a character type.

#### CODE



```
typeof( $\sigma$ [1])
```

## OUTPUT

```
Char
```

### 4.4.2 CHARACTER TYPES

**Character objects** ( `Char` ) are 32-bit primitive data types. They have a special literal representation and appropriate arithmetic behaviour. They can also be converted into numeric values representing a Unicode code point.

We can define a `Char` by using single quotes `' '`:

## CODE

```
my_char = ' $\pi$ '
```

## OUTPUT

```
my_char = ' $\pi$ ': Unicode U+03C0 (category Ll: Letter, lowercase)
```

This tells us the Unicode representation for  $\pi$ . If we perform a Google Search, we can see that, in fact, `U+03C0` is the Unicode representation of  $\pi$ .

Unicode characters can also be represented numerically. We can convert a `Char` object to its `Int` representation:

## CODE

```
begin
  my_int_char = '?'
  println(my_int_char)
  println(typeof(my_int_char))
  my_int_char = Int(my_int_char)
  println(my_int_char)
  println(typeof(my_int_char))
end
```

## OUTPUT

```
?
Char
63
Int64
```

If we perform a [Google Search](#), we can see that the numeric representation of the `?` Unicode character is, in fact, 63, and our new data type is `Int64`.

We can convert our numerical representation back to a `Char` type by performing the inverse operation:

## CODE

```
Char(my_int_char)
```

## OUTPUT

```
'?': ASCII/Unicode U+003F (category Po: Punctuation, other)
```

We can use multiple string & character methods such as unions, concatenations, interpolations, repetitions, conversions, and advanced [regex](#) techniques. We will not explore all the possibilities; the complete documentation can be consulted [here](#).

## 4.5 Boolean types

Boolean types can be defined by using lowercase letters:

## CODE

```
begin
    b = true
    t = false
end
```

## CODE

```
begin
    println(typeof(b))
    println(typeof(t))
end
```

## OUTPUT

```
Bool
Bool
```

In Julia, `Bool` is a subtype of `Integer`; `true` equals 1, while `false` equals 0. We can do numerical operations on `Bool` types without the need for any type conversion:

## CODE

```
b - 1
```

## OUTPUT

```
0
```

# 5. Native data structures

Julia has several native data structures. They are abstractions of data that represent some form of structured data. We will cover the most used ones. There are also multiple data structures not native to Julia, such as DataFrames and SparseArrays, but we won't be covering those here.

## 5.1 Tuples

A **tuple** is a fixed-length container that can hold multiple different types. It's an **immutable object**, meaning it cannot be modified after its instantiation.

To construct a tuple, we can use parentheses `()` to delimit the beginning and end, along with commas `,` as delimiters between values:

## CODE

```
my_tuple = (1, "2", '3', "four", "🚀")
```

## OUTPUT

```
my_tuple = (1, "2", '3', "four", "🚀")
```

We can index a tuple by using brackets `[]`:

## CODE

```
my_tuple[5]
```

## OUTPUT

```
"🚀"
```

What we cannot do, is mutate a tuple object:

## CODE

```
my_tuple[5] = λ
```

## OUTPUT

```
MethodError: no method matching setindex!{::Tuple{Int64, String, Char, String, String}, ::Int64, ::Int64}
top-level scope@Local: 1[inlined]
```

We can iterate over the items of a tuple (*we'll cover for loops in more detail soon enough*):

## CODE

```
for i in my_tuple
    println(i)
end
```

## OUTPUT

```
1
2
3
four
🚀
```

There's also a special type of tuple called `NamedTuple`. We will not cover it here, but it can be consulted in the [official documentation](#).

## 5.2 Ranges

A **range** in Julia represents an interval between start and stop boundaries. We can define a range by using the `start:stop` syntax:

## CODE

```
my_range = 1:7
```

## OUTPUT

```
my_range = 1:7
```

We can index a range and iterate over its elements:

## CODE

```
begin
    my_range_2 = 1:7
    println(my_range_2[7])

    for i in my_range_2
        println(i)
    end
end
```

## OUTPUT

```
7
1
2
3
4
5
6
7
```

We can also build an array comprehension (*similar to Python's list comprehensions*) by using a range in combination with a `for` loop, all enclosed in brackets `[]`:

## CODE

```
begin
    my_array_comp = [x for x in 1:7]
    println(my_array_comp)
end
```

## OUTPUT

```
[1, 2, 3, 4, 5, 6, 7]
```

## 5.3 Arrays

In Julia, there are no list objects as in Python. We instead have **arrays**. They are mutable, can be one-dimensional or multi-dimensional, and can hold multiple objects.

There are two main array subtypes in Julia:

- Vectors
- Matrices

### 5.3.1 VECTORS

**Vectors** are one-dimensional objects that can be defined using brackets:

## CODE

```
my_vector = [1, 2, 3]
```

If we take a look at our `my_vector` data type, we can see that we have a `Vector` containing `Int64` objects:

#### CODE

```
typeof(my_vector)
```

#### OUTPUT

```
Vector{Int64} (alias for Array{Int64, 1})
```

We can also declare a mixed-type `Vector` object:

#### CODE

```
begin
    my_vector_2 = [1, 2, "3"]
    typeof(my_vector_2)
end
```

#### OUTPUT

```
Vector{Any} (alias for Array{Any, 1})
```

When no supertype is given, the default one is `Any` – a predefined abstract type that all objects are instances of and all types are subtypes of. In type theory, `Any` is commonly called "*top*" because it is at the apex of the type graph.

### 5.3.2 MATRICES

We can declare **matrices** in multiple ways.

We can use a collection of vectors nested inside brackets `[]` (*it's important to note that, unlike Python, we're not using commas to separate each vector*):

#### CODE

```
begin
    my_matrix = [[1, 2] [3, 4] [5, 6]]
    println(typeof(my_matrix))
    println(my_matrix)
end
```

#### OUTPUT

```
Matrix{Int64}  
[1 3 5; 2 4 6]
```

We can also declare a matrix of undefined values by specifying it's dimensions and content's data type:

## CODE

```
begin  
  my_matrix_2 = Matrix{Float64}(undef, 4, 2)  
  println(typeof(my_matrix_2))  
  println(my_matrix_2)  
end
```

## OUTPUT

```
Matrix{Float64}  
[0.0 0.0; 0.0 0.0; 0.0 0.0; 0.0 0.0]
```

In Linear Algebra, it's common to use matrices of ones and zeros:

## CODE

```
begin  
  my_matrix_zeros = zeros(4, 2)  
  my_matrix_ones = ones(4, 2)  
  println(my_matrix_zeros)  
  println(my_matrix_ones)  
end
```

## OUTPUT

```
[0.0 0.0; 0.0 0.0; 0.0 0.0; 0.0 0.0]  
[1.0 1.0; 1.0 1.0; 1.0 1.0; 1.0 1.0]
```

It's also common to specify matrices of random values. We can do so by using the Base `rand` method:

## CODE

```
rand(5,5)
```

## OUTPUT

```
5x5 Matrix{Float64}:
 0.685521  0.667868  0.368505  0.579188  0.67113
 0.869676  0.477044  0.576164  0.717674  0.348186
 0.163335  0.257388  0.841889  0.469516  0.409196
 0.253942  0.527152  0.808858  0.800833  0.609731
 0.4401    0.718082  0.748828  0.284882  0.410565
```

This method will return a matrix of dimension  $n \times n$ , with `Float64` type values between 0 and 1.

If we would like to explore our matrix objects in more detail, we can employ dimension methods:

## CODE

```
begin
  my_matrix_rand = rand(5,5)
  println(length(my_matrix_rand))
  println(ndims(my_matrix_rand))
  println(size(my_matrix_rand))
end
```

## OUTPUT

```
25
2
(5, 5)
```

- The `length` method will return the total number of elements in our matrix.
- The `ndims` method will return the number of dimensions.
- The `size` method will return our matrix's size in row-column notation.

Finally, we can index our matrix similar to indexing other objects such as tuples or vectors:

## CODE

```
my_matrix_rand_2 = rand(2,5)
```

```
begin
  println(my_matrix_rand_2[1])
  println(my_matrix_rand_2[2, 1])
  println(my_matrix_rand_2[end])
end
```

## OUTPUT

```
0.9069052054266634
0.4401923900688668
0.8721676196514414
```



- `my_matrix_rand_2[1]` will return the first element of our matrix.
- `my_matrix_rand_2[2, 1]` will return the element located in the second row, first column.
- `my_matrix_rand_2[end]` will return the last element in our matrix. The `begin` method can also be used to get the first element.

Arrays are the base for linear algebra in Julia and many other languages such as Python (*by using `np.arrays`*). This is why there is a multitude of different methods we can use to manipulate these objects. We will not cover them in detail but can be consulted on the [Julia's official documentation page](#).

## 5.4 Pairs

**Pairs** hold two objects which typically belong to each other. They are similar to Python's dictionaries but are limited to one pair of objects. Pairs are specifically used in broadcasting operations, which we'll review later on.

We can define a `Pair` by using the following notation:

### CODE

```
my_pair = "My Number" => 7
```

We can access a Pair's elements by using the `first` and `last` methods:

### CODE

```
begin
    println(first(my_pair))
    println(last(my_pair))
end
```

### OUTPUT

```
My Number
7
```

## 5.5 Dicts

Dicts are mappings from keys to values. By mapping, we mean that if you give a `Dict` some key, the `Dict` can tell us which value belongs to that key. Dicts are mutable and accept multiple objects.

We can define a `Dict` using the following syntax:

### CODE

```
my_dict = Dict{"ONE" => 1, "TWO" => 2, "THREE" => 3}
```

Typically, keys are denoted by `string` type objects and have to be unique within a given `Dict`. If we accidentally define duplicated keys, Julia will keep the latter and discard the previous definition:

### CODE

```
begin
  my_dict_2 = Dict("ONE" => 1, "ONE" => 2, "THREE" => 3)
  println(my_dict_2)
end
```

## OUTPUT

```
Dict{"ONE" => 2, "THREE" => 3}
```

Similar to Python, we can retrieve a given value by referring to its key:

## CODE

```
my_dict["ONE"]
```

## OUTPUT

```
1
```

We can also substitute a given value inside our `Dict` object:

## CODE

```
begin
  my_dict["ONE"] = 7
  println(my_dict)
end
```

## OUTPUT

```
Dict{"ONE" => 7, "THREE" => 3, "TWO" => 2}
```

As we can see, this is an in-place operation that will mutate our `Dict` object.

We can also iterate over key-value pairs by using a `for` loop:

## CODE

```
for i in my_dict
  println(i)
end
```

## OUTPUT

```
"ONE" => 7
"THREE" => 3
"Two" => 2
```

We can do the same, but this time, extracting key-value pairs separately:

## CODE

```
for (i, j) in my_dict
    println(i, " => ", j)
end
```

## OUTPUT

```
ONE => 7
THREE => 3
TWO => 2
```

# 6. Mathematical operators

**Mathematical operators** in Julia work very similarly to Python's. We can consult the complete set by heading to the [official documentation page](#).

Expression	Name	Description
<code>+x</code>	unary plus	the identity operation
<code>-x</code>	unary minus	maps values to their additive inverses
<code>x + y</code>	binary plus	performs addition
<code>x - y</code>	binary minus	performs subtraction
<code>x * y</code>	times	performs multiplication
<code>x / y</code>	divide	performs division
<code>x ÷ y</code>	integer divide	$x / y$ , truncated to an integer
<code>x \ y</code>	inverse divide	equivalent to <code>y / x</code>
<code>x ^ y</code>	power	raises <code>x</code> to the <code>y</code> th power
<code>x % y</code>	remainder	equivalent to <code>rem(x,y)</code>

TABLE 3: MATHEMATICAL OPERATORS IN JULIA, EXTRACTED FROM [OFFICIAL DOCUMENTATION](#)

We can perform any mathematical operation using the following syntax:

## CODE

```
begin
    my_num_1 = 7
    my_num_2 = 2
    my_vec_1 = [3, 4, 5]
    println(my_vec_1 * my_num_1)
end
```

## OUTPUT

```
[21, 28, 35]
```

We can also use the updating operator forms for each case above. These operators update our variable without the need to redefine it:

Expression	Name	Description
<code>x += y</code>	binary plus	performs addition
<code>x -= y</code>	binary minus	performs subtraction
<code>x *= y</code>	times	performs multiplication
<code>x /= y</code>	divide	performs division
<code>x ÷= y</code>	integer divide	$x / y$ , truncated to an integer
<code>x \= y</code>	inverse divide	equivalent to <code>y / x</code>
<code>x ^= y</code>	power	raises <code>x</code> to the <code>y</code> th power
<code>x %= y</code>	remainder	equivalent to <code>rem(x,y)</code>

TABLE 4: MATHEMATICAL UPDATING OPERATORS IN JULIA, EXTRACTED FROM JULIA'S OFFICIAL DOCUMENTATION

## 7. Flow control

Flow control in Julia can be achieved by using multiple built-in methods. The most popular are:

- Logical operators
- Conditionals
- `For` loops
- `While` loops

### 7.1 Logical operators

There are six basic **logical or comparison operators** in Julia:

Expression	Name
<code>==</code>	equality
<code>!=</code> , <code>≠</code>	inequality
<code>&lt;</code>	less than
<code>&lt;=</code> , <code>≤</code>	less than or equal to
<code>&gt;</code>	greater than
<code>&gt;=</code> , <code>≥</code>	greater than or equal to

TABLE 5: LOGICAL OPERATORS IN JULIA, EXTRACTED FROM JULIA'S [OFFICIAL DOCUMENTATION](#)

We can perform a logical comparison by using the following syntax:

#### CODE

```
begin
    e = 1
    f = 2
    println(e>f)
end
```

#### OUTPUT

```
false
```

## 7.2 Conditionals

A complete Julia conditional evaluation includes 4 parts:

- `if`
- `elseif`
- `else`
- `end`

We can either stick with just the `if` `end` statement combination if we have only one condition to evaluate or include the whole structure:

#### CODE

```
begin
    for i in 1:10
        if i%2 != 0
            println("Odd number")
        else
            println("Even number")
        end
    end
end
```

## OUTPUT

```
Odd number
Even number
Odd number
Even number
Odd number
Even number
Odd number
Even number
Odd number
Even number
```

## 7.3 For loops

We have already seen some `for` loop examples; they are very similar to their Python counterpart, except that we don't require a colon `:` at the end of the statement, and we need to add an `end` statement at the end of our declaration:

### CODE

```
begin
  for i in 0:9
    println(i+1)
  end
end
```

## OUTPUT

```
1
2
3
4
5
6
7
8
9
10
```

## 7.4 While loops

Similarly, we can define a `while` loop by using the syntax below:

### CODE

```
begin
    i = 7

    while i >= 1
        println(i)
        i -= 1
    end
end
```

## OUTPUT

```
7
6
5
4
3
2
1
```

# 8. Functions

**Functions** in Julia, as in many other languages, are essential. Functions are similarly implemented in Julia compared to Python. Still, they have many additional features, such as **broadcasting** and native **multiple dispatch** support, which expand their functionality in ways Python simply can't by default.

## 8.1 Defining a function

We can define a function by using the following syntax:

### CODE

```
function my_fun(x,y)
    x + y
end
```

### OUTPUT

```
my_fun (generic function with 1 method)
```

We can then call our function:

### CODE

```
begin
    call_to_fun = my_fun(1, 2)
    println(call_to_fun)
end
```

## OUTPUT

```
3
```

Even though we did not include a `return` statement, our function will return the output of the only method available inside of it.

We can define our function in a more compact form:

## CODE

```
my_fun_2(x,y) = x + y
```

Since, as we have mentioned, Julia accepts Unicode characters as part of its syntax, we could even write our own `sum` function:

## CODE

```
Σ(x,y) = x + y
```

We can call it just as we would any other function:

## CODE

```
Σ(7, 7)
```

## OUTPUT

```
14
```

This non-return method works when we have one single value we would like to return, but we may also want to return multiple values:

## CODE

```
function my_fun_3(x, y)
    a = x*y
    b = x+y
    return a, b
end
```

We can then call our function:

## CODE



```
println(my_fun_3(7, 7))
```

## OUTPUT

```
(49, 14)
```

We can of course declare nested functions, thus expanding the functionality of our parent function.

## 8.2 Broadcasting

**Broadcasting** is an extremely powerful concept in Julia, especially when performing vector & matrix operations. It lets us broadcast operations over the elements of the input objects. Broadcasting can be achieved using the dot `.` operator, which applies to any function or arithmetic operation.

We can define a function `my_fun_b` that will take a matrix as input, square each of its elements, and return the result.

We will first start by creating a matrix and an `Int` variable that will serve as inputs:

## CODE

```
my_matrix_b = rand(4, 4)
```

We can then define our function `my_fun_b` :

## CODE

```
function my_fun_b(x)
    return x^2
end
```

If we call our function with `my_matrix_b` as its argument without broadcasting, we will get the squared matrix ( $M \times M$ ) as a result, and not the element-wise operation:

## CODE

```
display(my_fun_nb(my_matrix_b))
```

## OUTPUT

```
4×4 Matrix{Float64}:
 1.26661  0.519347  1.13055  1.23636
 2.17724  1.23979   1.87389  1.73158
 0.63514  0.201745   0.51771  0.589747
 0.809722 0.554337   0.859173 0.652899
```

This is not what we're looking for. Instead, we can use the broadcasting operator when calling our function. The dot `.` operator will go just after our function call and before the opening parenthesis `(` for our arguments:

## CODE

```
display(my_fun_nb.(my_matrix_b))
```

## OUTPUT

```
4×4 Matrix{Float64}:
 0.896748  0.0097358  0.165206  0.648777
 0.812765  0.904707   0.794022  0.309314
 0.198626  0.000761553  0.113611  0.094145
 0.0153391 0.158666   0.417942  0.133245
```

We can see that we now get the result we were looking for.

## 8.3 Functions with a bang !

The bang `!` symbol in Julia is used to differentiate mutating vs non-mutating operations. When we call a method along with `!`, it will mutate our input variable.

We can use the `sort()` method as example:

## CODE

```
begin
    my_vec_a = [1, 4, 5, 8, 3, 0]
    println(sort(my_vec_a))
    println(my_vec_a)
end
```

## OUTPUT

```
[0, 1, 3, 4, 5, 8]
[1, 4, 5, 8, 3, 0]
```

As we can see, the way we called our function did not mutate the original structure of `my_vec_a`.

If we want to mutate it, we can use `sort!()` instead of `sort()`:

## CODE

```
begin
    my_vec_b = [1, 4, 5, 8, 3, 0]
    println(sort!(my_vec_b))
    println(my_vec_b)
end
```

## OUTPUT

```
[0, 1, 3, 4, 5, 8]
[0, 1, 3, 4, 5, 8]
```



## Next steps

We covered a tiny sample of what Julia can do. This language has endless potential and can be used by many professionals and enthusiasts looking for a high-performance, bleeding-edge alternative to the current options.

Now that we know the basics of the Julia programming language, there are multiple paths we can choose to follow:

- **Data Science & Machine Learning:** [Julia for Data Scientists](#) would be a great next step for those interested in using this language for big data processing & parallelization, Machine Learning algorithm design & deployment, statistical analysis, and more.
- **Optimization:** [Julia for Optimization and Learning](#) imparted by the [Czech Technical University](#) in Prague, provides excellent introductory material for those interested in Optimization & Machine Learning techniques.
- **Linear Algebra:** Julia stands up when performing linear algebra-related operations. There is a huge collection of packages and documentation available. A great first step would be [Basic Linear Algebra in Julia](#), imparted by the extremely well-versed [Dr. Jane Herriman](#).
- **Integral & Differential Calculus:** No scientific language is complete without a robust set of calculus methods, and Julia, of course, is no exception. There is a [great series of articles](#) by [jverzani](#) aiming to cover the basics of calculus using Julia, ranging from simpler undergraduate concepts to more intermediate topics.
- **Documentation:** Julia can also be used for documentation purposes. In particular, the `Documenter.jl` package offers excellent capabilities to write in [Markdown](#) offering a simple and easy-to-understand interface.



## Conclusions

In this segment, we installed the Julia programming language from scratch along with Visual Studio as an IDE and the Visual Studio Julia extension as a handy tool. We also reviewed two great notebook environment options: JupyterLab and `Pluto.jl`.

Once we had our installations ready, we learned to use the Julia REPL from the Windows Terminal and from within VS Code using the Julia extension. We also learned how to create project environments, install packages within our environment, manage them appropriately, and write our first Julia program.

Finally, we introduced some of Julia's core concepts, accompanied by hands-on examples using `Pluto.jl` and `PlutoUI`.

Julia is a language that has been gaining consistent popularity throughout the last few years. It was introduced as a fresh approach to scientific programming and is sure to become a building block for aspiring Data Scientists in the near future. It has so many innovative features that it's hard to look the other way and continue using the well-established Data Science languages we have been using for several years.

Julia allows us to stop and think if what we're doing and how we're doing it is the most optimal way. It's an ambitious project that aims to change how we look at high-performance scientific computing.

One thing to consider is that Julia is fast-evolving; each iteration brings on new changes, which might be small but can also consist of a complete refactoring of base functionality. This is critical because a library that worked yesterday with a given syntax might not work the same way today. Still, this is always part of the process of any programming language, and really, the most exciting one; witnessing a group of passionate people build the foundations for the future is always inspiring.

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## §

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# References

- [Talk Julia, Setting Up VS Code for Julia](#)
- [Julia Data Science, Data Structures](#)
- [Julia Documentation, Data Types](#)
- [Julia Documentation, Functions](#)
- [Geeks for Geeks, Broadcasting across arrays in Julia](#)
- [Julia Documentation, Arrays](#)
- [Pluto Documentation, Pluto.jl](#)

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