GG3209 - Spatial Analysis with GIS

Second Part - Introduction to Python

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About this site

This book has been developed as part of the module **GG3209 – Spatial Analysis with GIS** at the School of Geography and Sustainable Development, University of St Andrews. This module is spitted in two parts, the first 4 weeks includes QGIS and Multi-criteria evaluation, the second part related to the use of Python for the use and analysis of spatial data.

This part will establish a comprehensive introduction to **Python** (an easy-to-learn and powerful programming language) and its use for manipulating spatial data and deploying spatial analysis models. Python has been cataloged as one of the most popular programming technologies and is widely used as a scripting language in the GIScience world. If you have signed to this module you will learn how to use Python in multiple environments, more specifically using a popular tool called Jupyter Notebooks, then learn how to manipulate vector and raster data and finish by integrating spatial modelling using coding environments and clustering methods as helpful methodologies for dissertations.

This module include Lecture+Lab sessions. Lectures will be delivered first, followed by lab practices included in this site. Students will be expected to work on these during the lab sessions but may also have to continue their own for the rest of the week, since the scheduled time may not be sufficient to finish everything.

All students enrolled in GG3209 have access to the University's ArcGIS Online **Organisational Account** using their University credentials. We will use this platform in some of the Labs. If you havent experimenting and working with this platform before, to get started, please log in at: https://uostandrews.maps.arcgis.com

Introduction

Intro

Step 1. Python Environment Installation

This guide provides step-by-step instructions for setting up the Python environment for second part of the **module GG3209** on Windows and macOS. The environment includes all necessary libraries for data handling, clustering, visualization, large datasets, and hotspot analysis.

Estimated time to install: 20 to 30 minutes.

Note: Make sure you have an stable internet connection. If you are using **eduroam** at the university, you might experience delays or issues when the internet connection isn't stable, if that is the case make sure you have a stable connection at home to complete this process properly.

Prerequisites

Before starting, ensure you have:

- ☐ A stable internet connection (large downloads required)
- ☐ At least 5GB of free disk space
- ☐ Administrator privileges on your computer
- ☐ Basic familiarity with command line interface (we will have a show demo about this during the lectures)

If you don't know how to validate this, please make an appointment with our IT service person who can support you with this at gsditsupport@st-andrews.ac.uk

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1. Installing Miniconda

Miniconda provides a clean, minimal Python installation with only essential packages. This ensures all students start with identical environments and reduces potential conflicts. It's lightweight, fast, and gives us complete control over installed packages. The installation of this program relies on the operating system you have, thus use the instructions based on that:

Windows Installation

1. **Download Miniconda**:
   - Visit https://docs.conda.io/en/latest/miniconda.html
   - Download **"Miniconda3 Windows 64-bit"** (approximately 50MB)
   - **Important**: Download the Python 3.10 version specifically
2. **Install Miniconda**:
   - Double-click the downloaded `.exe` file
   - Click "Next" through the installation wizard
   - **CRITICAL**: When asked about PATH, select **"Add Miniconda3 to my PATH environment variable"**
   - Accept all other default settings
   - Complete installation (takes 2-3 minutes)
3. **Verify Installation**:
   - Open **Command Prompt** (Press `Win + R`, type `cmd`, press Enter)
   - Type `conda --version` and press Enter
   - You should see: `conda 23.x.x` (or similar version number)
   - Type `python --version` and press Enter
   - You should see: `Python 3.10.x`

macOS Installation

1. **Download Miniconda**:
   - Visit https://docs.conda.io/en/latest/miniconda.html
   - **For Apple Silicon Macs (M1/M2)**: Download "Miniconda3 macOS Apple M1 64-bit pkg"
   - **For Intel Macs**: Download "Miniconda3 macOS Intel x86 64-bit pkg"
   - **Important**: Download the Python 3.10 version specifically
2. **Install Miniconda**:
   - Double-click the downloaded `.pkg` file
   - Follow the installation wizard
   - Accept all default settings
   - Complete installation
3. **Verify Installation**:
   - Open **Terminal** (Press `Cmd + Space`, type "Terminal", press Enter)
   - Type `conda --version` and press Enter
   - You should see: `conda 23.x.x` (or similar version number)

- Type `python --version` and press Enter
- You should see: `Python 3.10.x`

Post-Installation Setup (All Students)

After successful installation, run these commands to ensure consistency:

```
# Update conda to latest version
conda update -n base -c defaults conda

# Configure conda for optimal performance
conda config --set auto_activate_base false
conda config --add channels conda-forge
conda config --set channel_priority strict

# Verify configuration
conda info
```

Expected Output: You should see conda-forge listed as a channel with highest priority.

---

2. Creating the Environment

Step 1: Download the Environment File

Save the environment configuration as `environment.yml` in a folder of your choice (e.g., `Documents/gg3209/`).

Step 2: Open Command Line Interface

Windows Students

- Press `Win + R`, type `cmd`, press Enter
- **Alternative**: Search for "Command Prompt" in Start Menu
- **Important**: Use Command Prompt, NOT PowerShell or other terminals

macOS Students

- Press `Cmd + Space`, type "Terminal", press Enter
- **Alternative**: Go to Applications > Utilities > Terminal
- **Important**: Use Terminal, NOT other command line apps

Step 3: Navigate to Your Project Directory

All students should create the same folder structure:

```
# Windows students
mkdir C:\gg3209 #sds stands for spatial dtata science
cd C:\gg3209

# macOS students
mkdir ~/gg3209
cd ~/gg3209
```

Step 4: Download and Verify Environment File

Before creating the environment, ensure you have the correct file:

1. Save the `environment.yml` file in your project directory. This file is located in Moodle, go there and download it and place it in the project directory you created earlier.
2. Verify the file exists:

```
# All students run this command
dir environment.yml    # Windows
ls environment.yml     # macOS
```

You should see the file listed. If not, ensure you saved it correctly.

Step 5: Create the Environment (Critical Step)

This is where consistency matters most:

```
# Create environment from file
conda env create -f environment.yml

# This will take 15-30 minutes
# You will see many packages being downloaded and installed
# Wait for "done" message before proceeding
```

Expected Output:

```
Collecting package metadata (repodata.json): done
Solving environment: done
Preparing transaction: done
Verifying transaction: done
Executing transaction: done
#
# To activate this environment, use
#
#     $ conda activate spatial-data-science
#
# To deactivate an active environment, use
#
#     $ conda deactivate
```

Step 6: Activate the Environment

All students must activate the environment before using it – THIS IS VERY IMPORTANT:

```
# Activate the environment
conda activate gg3209
```

Success Indicator: Your command prompt should now show `(gg3209)` at the beginning:

```
# Windows example
(gg3209) C:\gg3209>

# macOS example
(gg3209) username@computer:~/gg3209$
```

Step 7: Final Verification

All students run the same verification script:

Once you have created your python environment, now it is important you test that everything is properly installed. Using the same `terminal` or `command prompt` window run the following command.

```
# Make sure environment is activated (optional if you know you have activated it)
conda activate gg3209

# Run the test
python test_installation.py

------
# Windows example
(gg3209) C:\gg3209\> python verification_script.py

# macOS example
(gg3209) username@computer:~/gg3209/$ python verification_script.py
```

Expected Output for All Students:

```
Python version: 3.10.x
Python location: [path to conda environment]
  All required libraries imported successfully!
  Environment setup is complete and consistent!
  GeoPandas version: 1.1.1
  Pandas version: 2.3.1
  NumPy version: 1.26.4
```

If successful, you should see version numbers and check-marks.

---

3. Running Jupyter Lab

Starting Jupyter Lab

```
# Make sure environment is activated (optional if you know you have activated it)
conda activate gg3209

# Make sure you are in your project directory e.g. GG3209
cd GG3209

# Launch Jupyter Lab
jupyter lab
```

This will:

- Start the Jupyter server

- Open your default web browser

- Display the Jupyter Lab interface

Creating Your First Notebook

1. Click "Python 3 (ipykernel)" under "Notebook"
2. Test with a simple spatial analysis:

```
import geopandas as gpd
import matplotlib.pyplot as plt
import geodatasets

# Create a simple test
world = gpd.read_file(geodatasets.get_path("naturalearth.land"))
world.plot(figsize=(10, 6))
plt.title('World Map Test')
plt.show()
```

Stopping Jupyter Lab

- In your browser: File > Shut Down
- In command line: Press `Ctrl + C` (Windows) or `Cmd + C` (Mac)

---

4. GG3209-Specific Setup Instructions

First Day of Class Checklist

All students must complete before first lab:

- ☐ **Install Miniconda** (Python 3.10)
- ☐ **Create spatial-data-science environment**
- ☐ **Activate environment successfully**
- ☐ **Run verification script** (must pass)
- ☐ **Start Jupyter Lab** (must open in browser)
- ☐ **Create test notebook** with basic spatial analysis

Weekly Environment Check

Run this command weekly to ensure consistency:

```
python -c "
import geopandas as gpd
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import folium
from esda.getisord import G_Local
from sklearn.cluster import DBSCAN
print(' Environment is working correctly')
print(f' GeoPandas version: {gpd.__version__}')
print(f' Pandas version: {pd.__version__}')
"
```

Submission Requirements

For all assignments, include this environment information:

```
# Add this cell at the top of every notebook
import sys
import geopandas as gpd
import pandas as pd

print(f"Python version: {sys.version}")
print(f"GeoPandas version: {gpd.__version__}")
print(f"Pandas version: {pd.__version__}")
print(f"Environment: gg3209")
```

---

5. Next Steps

Once your environment is set up:

1. **Complete the verification tests**
2. **Try the sample notebook**
3. **Explore the example datasets (Data Sources section)**
4. **Begin the Guideline Introduction to GIT**
5. **Now you are all set to start with Lab No 1, Lab No 2...and so on**
6. **Make sure you push your changes, updates and work regularly to your Repo in GitHub.**

Your python environment for this course `GG3209` is now ready. Now you need to install GIT and create a GitHub account to have everything you need to practice all your Python skills., there are some steps you need to recall while you work on this course, but with practice you will eventually memorise most of the critial steps.

Move to Step No 2.

Useful resources

Learning Materials

- **Geopandas Documentation**: https://geopandas.org/
- **PySAL Documentation**: https://pysal.org/
- **Spatial Data Science Book**: https://geographicdata.science/book/

Data Sources

- **Natural Earth**: https://www.naturalearthdata.com/
- **OpenStreetMap**: https://www.openstreetmap.org/
- **Census Data**: https://www.census.gov/

Community Support

- **Stack Overflow**: Use tags `geopandas`, `spatial-analysis`, `python`
- **GitHub Issues**: For specific library problems
- **Reddit**: r/gis and r/Python communities

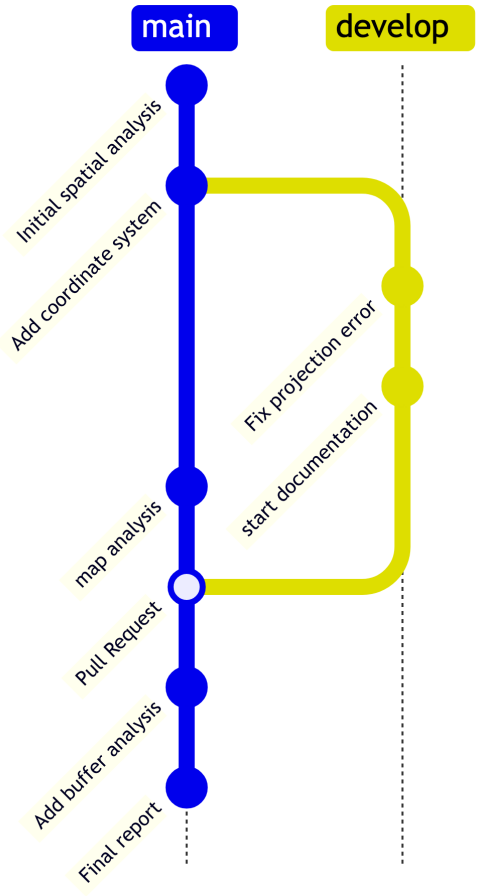
This guide was created for the GG3209 Spatial Analysis with GIS students at SGSD University of St Andrews. For questions or suggestions, please create an issue in this book repository. 2025

Step 2. Introduction to GIT

What is Version Control?

Version control is a system that records changes to files over time so that you can recall specific versions later. Think of it as a detailed history of your project that allows you to:

- Track every change made to your files
- Revert to previous versions when needed
- Collaborate with others without conflicts
- Understand who made what changes and when



Estimated time to install: 40 minutes.

Why Version Control Matters in Spatial Data Science

In spatial data science, you're often working with:

- **Complex datasets**: Shapefiles, rasters, GPS data, satellite imagery
- **Multiple software tools**: R, Python, QGIS, ArcGIS
- **Iterative analysis**: Testing different spatial models and parameters
- **Collaborative projects**: Working with field teams, other researchers
- **Reproducible research**: Ensuring your spatial analysis can be replicated

Common scenario

Imagine you're analyzing urban green spaces for any kind of project using R, and then you have something like:

```
urban_greenspace_analysis.R
urban_greenspace_analysis_v2.R
urban_greenspace_analysis_v2_final.R
urban_greenspace_analysis_v2_final_ACTUALLY_FINAL.R
urban_greenspace_analysis_v2_final_ACTUALLY_FINAL_supervisors_comments.R
```

Sound familiar? This approach leads to:

- Confusion about which version is current
- Lost work when files get overwritten
- Difficulty tracking what changed between versions
- Problems when collaborating with others

Git and GitHub

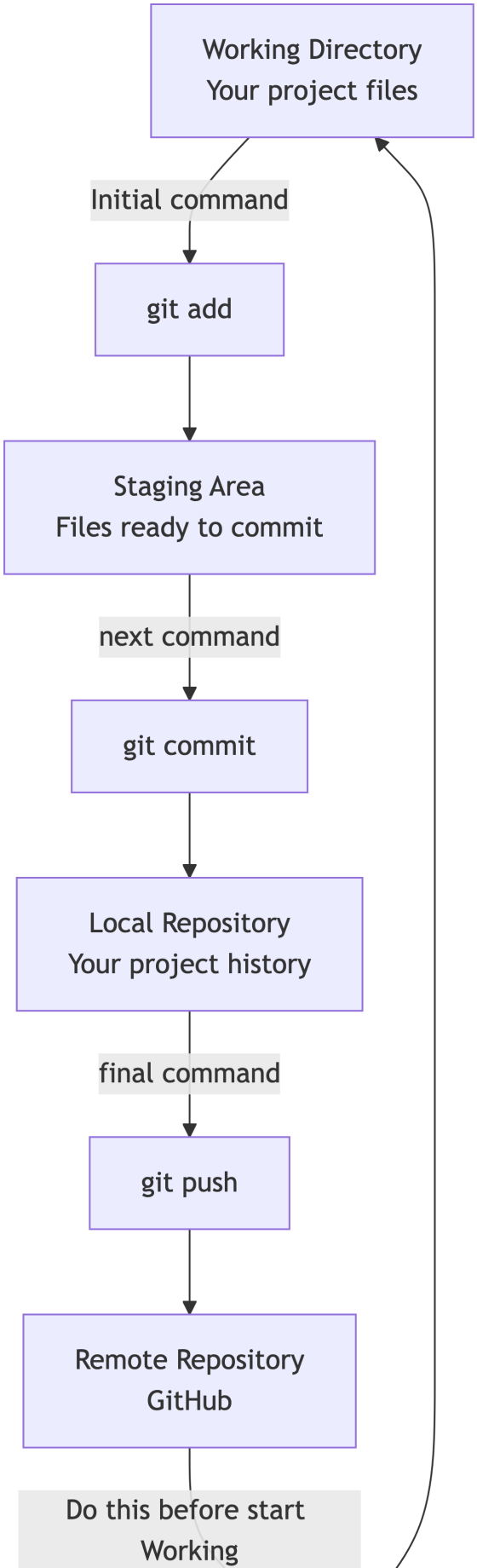
Another important component we need in our environment is **git**, the tool that provides version control for any of our projects. While version control is a systematic approach to recording changes you make in a file or set of files over time.

This is important, especially if you work with other collaborators, as you can track the history, see what changed and recall specific versions if needed. In this course, we will incorporate git to teach you how to create a branch, clone someone else's repositories, and give you a brief introduction to this important workflow, but also how you can commit your progress in one of the most popular **git tools** currently available. GitHub.

Key Terminology

- **Repository (repo)**: A folder containing your project files and their complete history
- **Commit**: A snapshot of your project at a specific point in time
- **Remote**: A version of your repository stored on a server (like GitHub)
- **Clone**: Creating a local copy of a remote repository
- **Push**: Sending your local changes to the remote repository
- **Pull**: Retrieving changes from the remote repository to your local copy

The Git Workflow

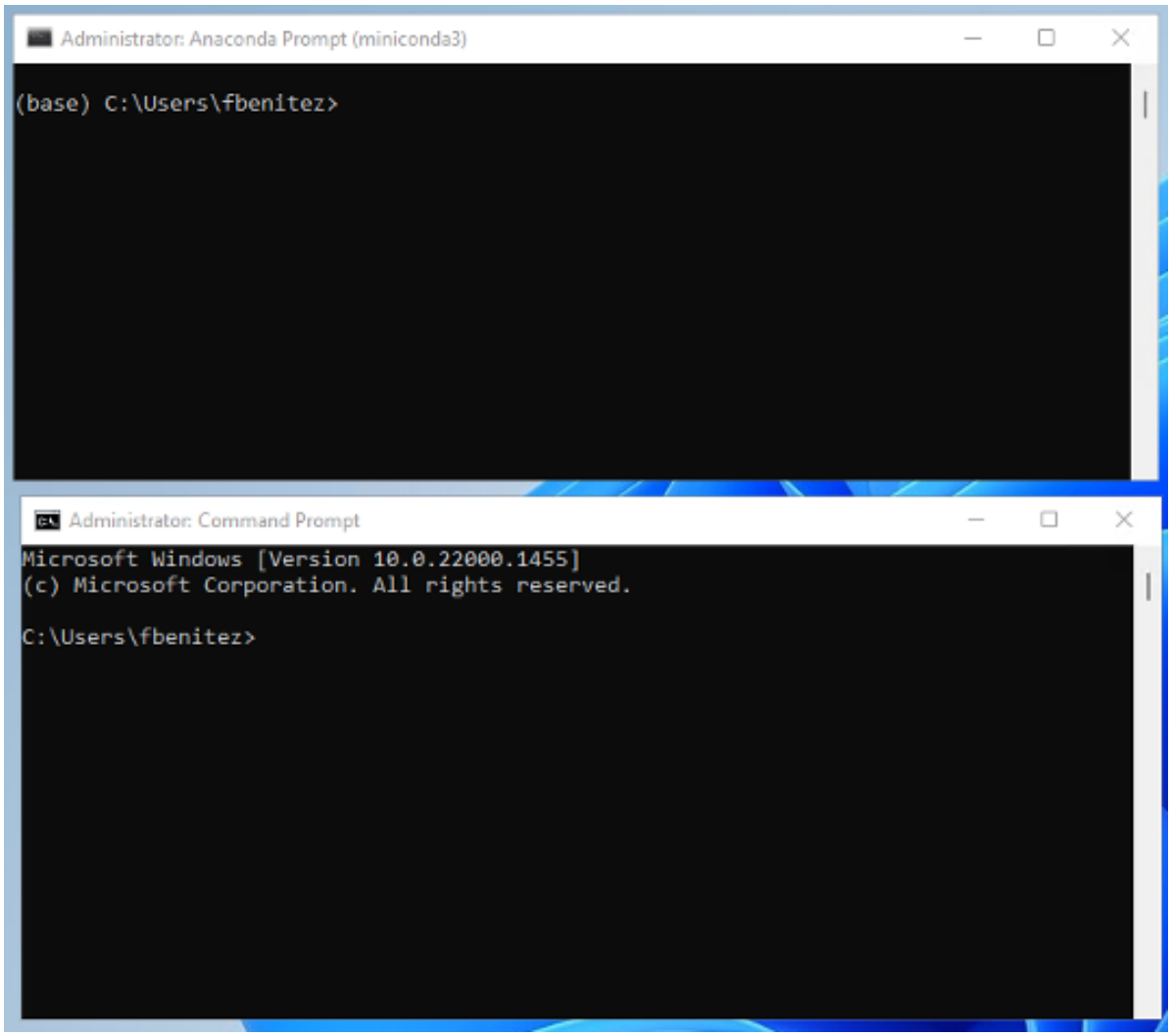


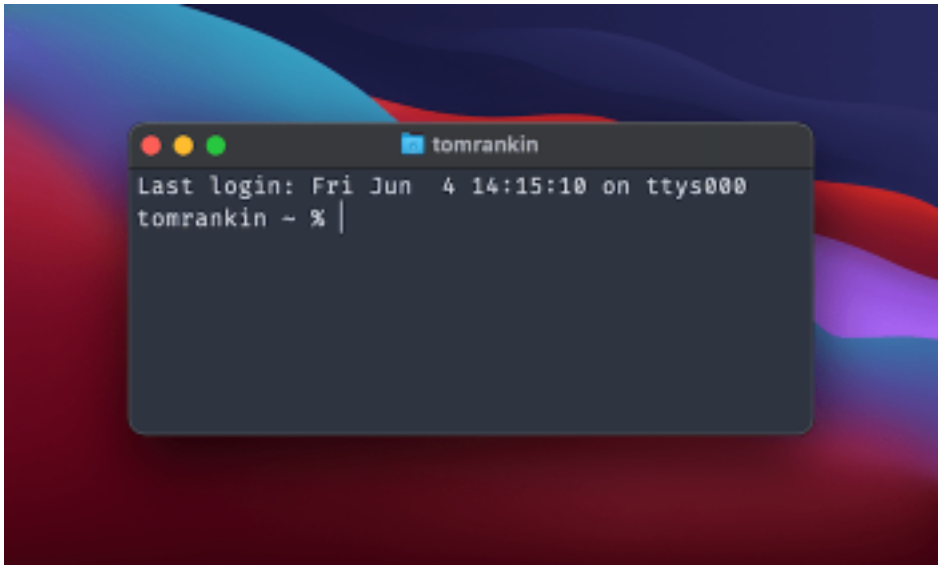
Basic Git Workflow

Get familiar with the Command Prompt or Terminal.

Before we continue with the installations and configurations, for the purpose of these labs, you need to get familiar with this interface and, more importantly, feel comfortable using them. In the following instructions, I will describe some steps to guide you in using the **Command prompt/Terminal.**

There are certain differences in the commands you will use in `windows` and `macOS`; make sure you test those commands and get the appropriate outcome.

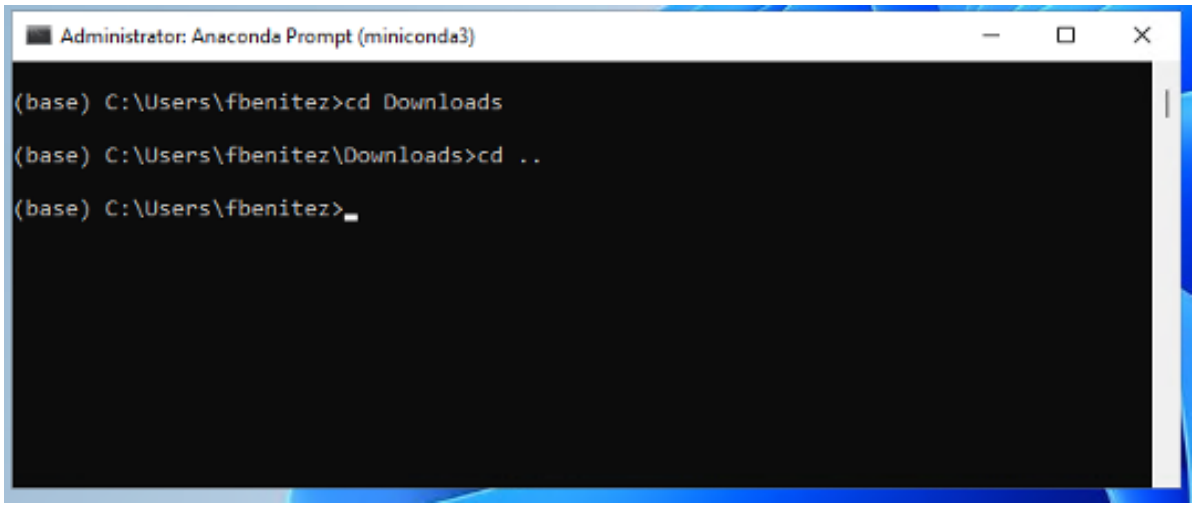

Administrator: Anaconda Prompt (miniconda3)
(base) C:\Users\fbenitez>
Administrator: Command Prompt
Microsoft Windows [Version 10.0.22000.1455]
(c) Microsoft Corporation. All rights reserved.
C:\Users\fbenitez>



Commands to move through drives and directories:

`cd`—Short for "change directory", to move through the directory structure (in the same drive), as in cd `C:\Users\fbenitez\Downloads`

`cd..` —to move to the upper level in your directories, so if you need to move from `C:\Users\fbenitez\Downloads` to `C:\Users\fbenitez\`



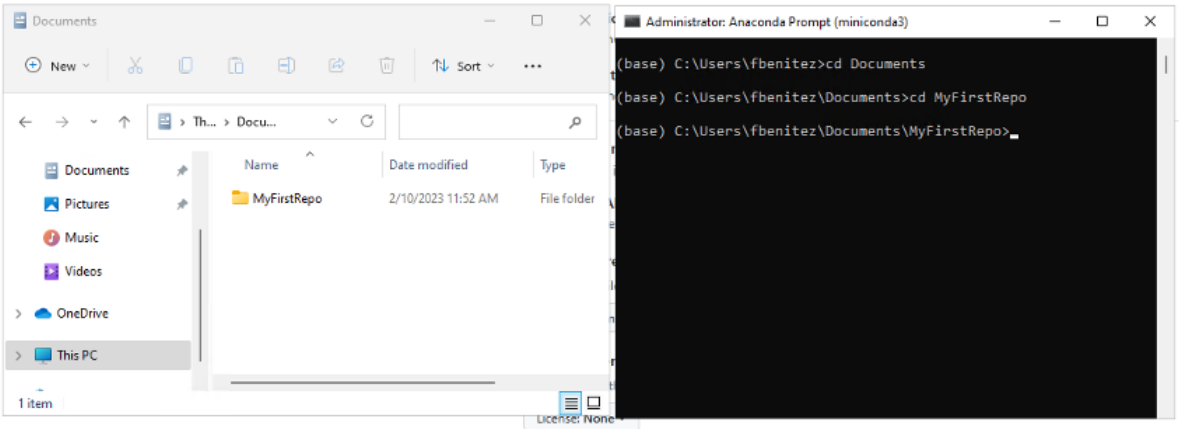
`X:` —To switch to a different drive, type the drive name followed by colon, as in D: to switch to drive D:\

`cls` (Windows) or clear (macOS) —To clean your terminal, it would help you to have a clean terminal and avoid mistakes.

`dir`(windows)

`ls` (macOs) —To list current directory contents.

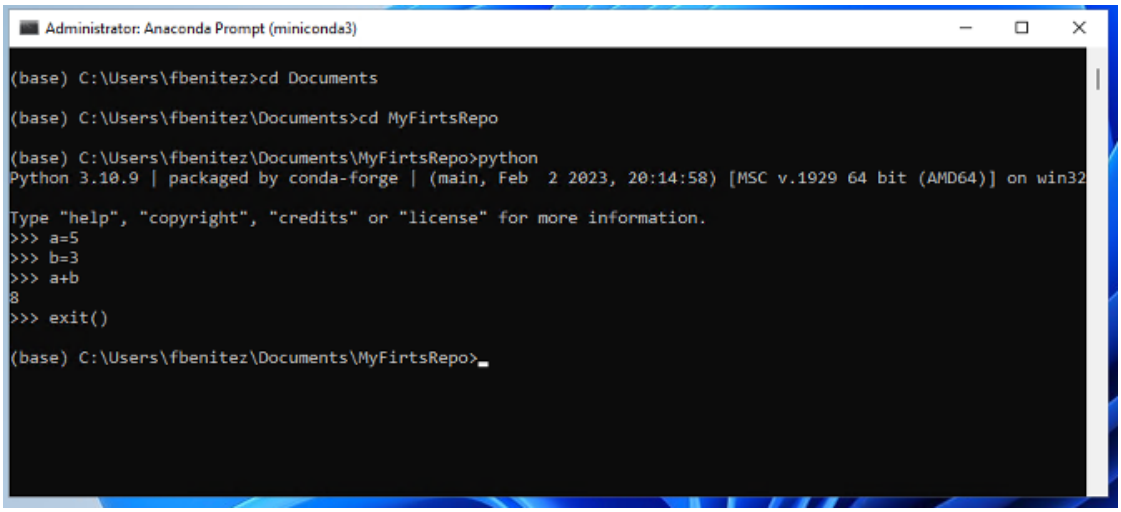
1. Go to your Documents folder in your computer. Create a folder call it **MyFirstRepo**
2. Open a **terminal/command prompt**, browse from the folder you are in to the new one, like the following illustrations.



You can also use some commands to run programs in your system which I know sounds silly as we are used to finding the icon and tap/click to get it open, but that's what happens underneath every time you open a program, here are some examples:

`python` —Starting the python command line interface, you can use the `exit()` command to get out of the python interface, and recover the terminal mode.

3. Try the example illustrated in the following image:


Administrator: Anaconda Prompt (miniconda3)
(base) C:\Users\fbenitez>cd Documents
(base) C:\Users\fbenitez\Documents>cd MyFirtsRepo
(base) C:\Users\fbenitez\Documents\MyFirtsRepo>python
Python 3.10.9 | packaged by conda-forge | (main, Feb 2 2023, 20:14:58) [MSC v.1929 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>> a=5
>>> b=3
>>> a+b
8
>>> exit()
(base) C:\Users\fbenitez\Documents\MyFirtsRepo>

Step 1: Creating a GitHub Account

Now, let's create your own GitHub Account. **GitHub**[1] is a web-based platform that hosts Git repositories, providing developers with tools for version control and collaboration. It combines Git, a powerful version control system, with features that facilitate collaboration and project management.

1.1 Sign Up for GitHub

1. Go to github.com
2. Click "Sign up"
3. Choose a username (take a note of this as you will use it later in this Lab)
4. Use your university email address ideally., but you can opt to use another email, just recall it when you need to recover your password. (take a note of this as you will use it later in this Lab)
5. Create a strong password
6. Verify your account

1.2 Configure Your Profile

There is a chance you won't open GitHub for anything else than this course, but also there is another chance where you will ended up working as spatial data scientist, or consultant into a collaborative development team. If that is your case, improving and configuring your GitHub account, as well as familiarizing about how it works would be definitively beneficial for you. For instance there are lot of companies or institutions who are asking or expecting you to have some well-curated repositories that prove your skills in Python and GitHub. Thus take some time to enhance your profile by adding this little extra information.

1. Add a profile picture
2. Add a bio mentioning your interest in spatial data science
3. Include your university affiliation
4. Consider making your profile public for academic networking

[1] https://www.geeksforgeeks.org/what-is-github-and-how-to-use-it/

Step 2: Installing and Configuring Git

Git[2] is a **distributed version control system** used to track changes in source code during software development. It helps multiple developers collaborate on a project by managing changes to files and coordinating work on those files.

2.1 Installing Git

Windows

1. Download Git from git-scm.com
2. Run the installer
3. Use default settings (recommended)
4. Choose "Git Bash" as your terminal

macOS

1. Install via Homebrew: `brew install git`
2. Or download from git-scm.com

Linux

```
# Ubuntu/Debian
sudo apt-get install git

# CentOS/RHEL
sudo yum install git
```

[2] https://git-scm.com/book/en/v2/Getting-Started-What-is-Git%3F

2.2 Initial Git Configuration

Open your terminal (Git Bash on Windows, Terminal on macOS/Linux) and run:

```
# Set your name (use your real name)
git config --global user.name "Your Name"

# Set your email (use your GitHub email)
git config --global user.email "your.email@st-andrews.ac.uk"

# Verify configuration
git config --list
```

Step 3: Creating Your First Local Repository

3.1 Setting Up a Project Structure

Now, in order to practice and validate that Git has been properly installed, let's create a fictional spatial data science project for analyzing urban heat islands, but let's try to use the terminal or the command prompt windows to practice.

1. Open a Terminal or Command prompt and run the following commands.

```
# Create project directory
mkdir urban_heat_island_analysis
cd urban_heat_island_analysis

# Create typical spatial data science structure
mkdir data
mkdir data/raw
mkdir data/processed
mkdir scripts
mkdir outputs
mkdir docs
```

3.2 Initialize Git Repository

```
# Initialize git repository
git init
```

This creates a hidden `.git` folder that stores all version control information.

3.3 Create Project Files

We will generate several files within this pilot project, so you can see how the repo can evolve and changes over time in the same way it happens when you work on a real project. The first file you need is the README which helps to describe what your project or repo is about.

Create a README file:

```
# Create README.md
touch README.md
```

Open the `README.md` file and add content:

```
# Urban Heat Island Analysis

## Project Overview
This project analyzes urban heat island effects in [Your City] using satellite thermal data a

## Data Sources
- Landsat 8 thermal infrared data
- OpenStreetMap building footprints
- Local weather station data

## Methods
- Temperature retrieval from satellite imagery
- Spatial interpolation techniques
- Statistical analysis of temperature patterns

## Software Requirements
- R (version 4.0+)
- Required packages: sf, terra, ggplot2, dplyr

## File Structure

urban_heat_island_analysis/
   data/
    raw/ # Original data files
    processed/ # Cleaned and processed data
   scripts/ # R scripts for analysis
   outputs/ # Maps, plots, and results
   docs/ # Documentation and reports
```

```
## Contact
[Your Name] - [Your Email]
```

Create a .gitignore file:

Warning: This is a very essential and relevant step when you work with repositories, in particular when working with spatial data science as we usually have to deal with large datasets, however cloud platforms –Github have storage limitations (e.g 50MB, 100MG). Sometimes also the jupyter notebooks can weight more than the storage limitations given by github. Therefore is super IMPORTANT that you create a file that tells your local repo to ignore those big files so you don't have any trouble when you `push` the files to the cloud.

```
touch .gitignore
```

Open the `.gitignore` file and add common files to ignore, you could add more later, or you can also add entire folders:

```
# R files
.Rproj.user
.Rhistory
.RData
.Ruserdata
*.Rproj

# Data files (large files)
*.tif
*.shp
*.dbf
*.prj
*.shx
*.zip

# Temporary files
*~
*.tmp
*.temp

# OS files
.DS_Store
Thumbs.db

# Log files
```

```
*.log

# Jupyter Notebook
.ipynb_checkpoints

# IPython
profile_default/
ipython_config.py
__pycache__/
*.py[codz]
*$py.class
```

3.4 Your First Commit

```
# Check status
git status

# Add files to staging area
git add README.md
git add .gitignore

# Or add all files
git add .

# Commit with descriptive message
git commit -m "Initial commit: Add project structure and README"
```

Step 4: Connecting Local Repository to GitHub

4.1 Create GitHub Repository

1. Log in to github.com
2. Click the "+" icon in the top right
3. Select "New repository"
4. Repository name: `urban_heat_island_analysis`
5. Description: "GG3209 pilot project to analyzing urban heat island effects"
6. Keep it public (for academic sharing)
7. **Don't** initialize with README (we already have one)
8. Click "Create repository"

4.2 Connect Local Repository to GitHub

GitHub will show you commands to run. Copy and paste these **into your terminal:**

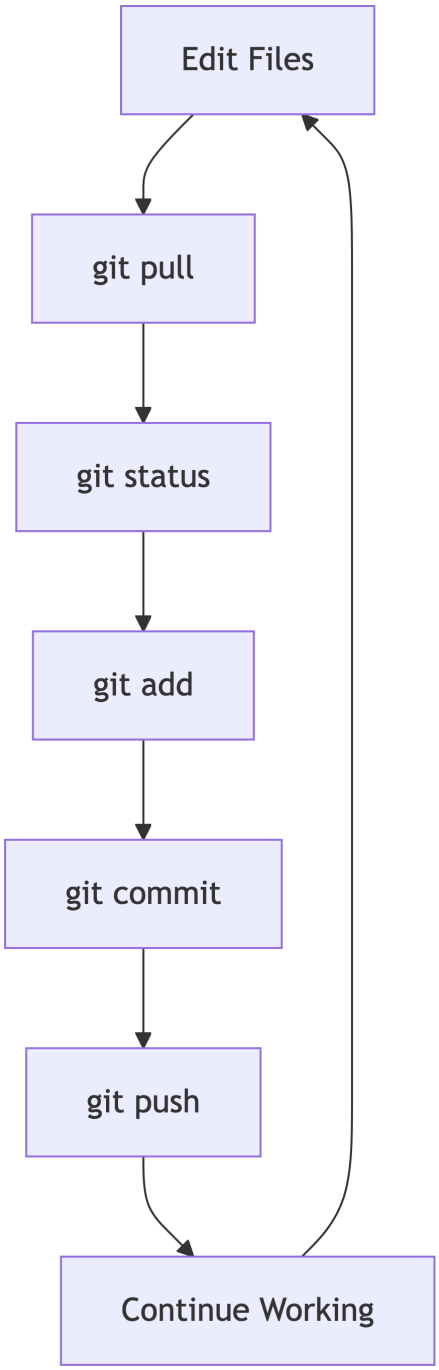
```
# Add GitHub as remote origin
git remote add origin https://github.com/yourusername/urban_heat_island_analysis.git #Replace

# Verify remote connection
git remote -v

# Push your local repository to GitHub
git push -u origin main
```

4.3 Verify Connection

1. Refresh your GitHub repository page
2. You should see your README.md and .gitignore files
3. Your commit message should be visible

Step 5: Essential Git Commands for Daily Use

5.1 The Basic Workflow

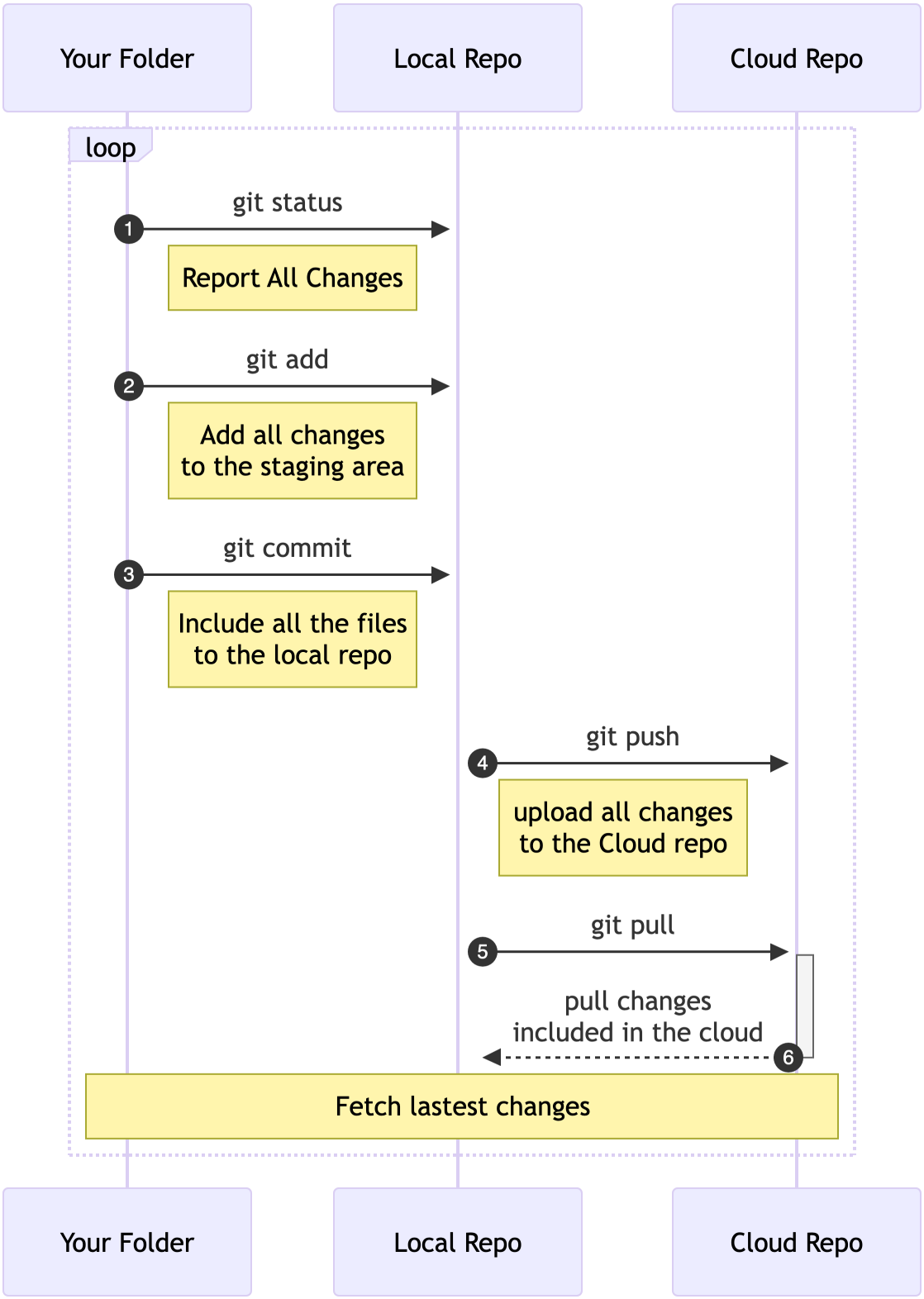


Daily Git Workflow

It is a bit complicated to understand what is underneath all this commands, so the following sequence-diagram represents how information, in particular how the modifications of your files moves around the version control system, thus it is easier for you to understand why do we need to run several commands when we use **git**.

Initially you have three folders. One is called **Your Folder** (this is where all your project are located, eg. Lab No 1, GG3209, etc), then you have a **Local repo** (a hidden folder that include all the components of version control or git) and finally the **Cloud Repo**, which is a folder located in the Cloud (e.g GitHub). The goal is to make sure we have all our editions sync and safe in the Cloud, so if eventually our computers breaks, we have a safe and updated copy of our project stored in the Cloud.

This is how a traditional workflow looks like when you work with Git and GitHub, study the steps and make sure you understand what the role of each command is. I expect you to work using these commands during the labs of this module.


Your Folder
Local Repo
Cloud Repo
loop
git status
1
Report All Changes
git add
2
Add all changes
to the staging area
git commit
3
Include all the files
to the local repo
git push
4
upload all changes
to the Cloud repo
git pull
5
pull changes
included in the cloud
6
Fetch lastest changes
Your Folder
Local Repo
Cloud Repo

5.2 Checking Status and History

```
# Check what files have changed
git status

# View commit history
git log

# View commit history (compact)
git log --oneline

# View changes in files
git diff
```

5.3 Adding and Committing Changes

Let's add a spatial analysis script:

```
# Create new R script
touch scripts/temperature_analysis.R
```

Add some content to `scripts/temperature_analysis.R`:

```
# Urban Heat Island Analysis
# GG3209 - Spatial Data Science
# Author: [Your Name]
# Date: [Current Date]

# Load required packages
library(sf)
library(terra)
library(ggplot2)
library(dplyr)

# Read temperature data
# temp_data <- rast("data/raw/landsat_thermal.tif")

# Read city boundary
# city_boundary <- st_read("data/raw/city_boundary.shp")
```

```
# TODO: Add temperature extraction analysis
# TODO: Add spatial interpolation
# TODO: Create temperature maps
```

Now commit these changes:

```
# Add the new script
git add scripts/temperature_analysis.R

# Commit with descriptive message
git commit -m "Add initial temperature analysis script

- Set up basic structure for thermal analysis
- Added required package imports
- Created placeholders for main analysis steps"

# Push to GitHub
git push origin main
```

5.4 Working with Multiple Files

Add more project files:

```
# Create data processing script
touch scripts/data_preprocessing.R

# Create visualization script
touch scripts/create_maps.R

# Add all new files
git add scripts/

# Commit all changes
git commit -m "Add data preprocessing and mapping scripts"

# Push to GitHub
git push origin main
```

5.5 Viewing and Understanding Changes

```
# See what changed in your last commit
git show

# Compare current files with last commit
git diff HEAD~1

# See changes in a specific file
git diff scripts/temperature_analysis.R
```

Step 6: Collaboration Workflow

6.1 Cloning an Existing Repository

When joining a collaborative project:

```
# Clone a repository
git clone https://github.com/username/repository-name.git

# Navigate to the cloned directory
cd repository-name
```

6.2 Keeping Your Local Repository Updated

```
# Fetch latest changes from GitHub
git pull origin main

# This is equivalent to:
git fetch origin main
git merge origin/main
```

6.3 Best Practices for Collaboration

1. **Always pull before starting work**:

```
git pull origin main
```

2. **Make small, frequent commits**:

```
git add specific_file.R
git commit -m "Fix coordinate system transformation bug"
```

3. **Write clear commit messages**:

```
# Good commit messages
git commit -m "Add buffer analysis for green spaces"
git commit -m "Fix projection error in temperature raster"
git commit -m "Update README with data sources"

# Poor commit messages (avoid these)
git commit -m "stuff"
git commit -m "fixes"
git commit -m "work"
```

Step 7: Handling Common Scenarios In Spatial Data Science

7.1 Working with Large Data Files

Spatial data files can be very large. Use `.gitignore` to exclude them:

```
# Add to .gitignore
echo "*.tif" >> .gitignore
echo "*.shp" >> .gitignore
echo "*.nc" >> .gitignore
echo "data/raw/*" >> .gitignore

# Commit the updated .gitignore
git add .gitignore
git commit -m "Update gitignore for large spatial data files"
```

7.2 Documenting Data Sources

Create a data documentation file:

```
touch docs/data_sources.md
```

Add comprehensive data documentation:

```
# Data Sources

## Landsat 8 Thermal Data
- **Source**: USGS EarthExplorer
- **Date**: 2023-07-15
- **Scene ID**: LC08_L1TP_015033_20230715_20230725_02_T1
- **Spatial Resolution**: 30m
- **Bands Used**: Band 10 (Thermal Infrared)
```

```
## City Boundary
- **Source**: OpenStreetMap
- **Downloaded**: 2023-08-01
- **Format**: Shapefile
- **Coordinate System**: WGS84 UTM Zone 33N

## Weather Station Data
- **Source**: Local Meteorological Service
- **Period**: 2023-07-01 to 2023-07-31
- **Variables**: Temperature, Humidity, Wind Speed
- **Temporal Resolution**: Hourly
```

7.3 Version Control for Analysis Results

Track your analysis outputs:

```
# Create results summary
touch outputs/analysis_summary.md

# Add and commit
git add outputs/analysis_summary.md
git commit -m "Add initial analysis summary template"
```

Step 8: Advanced Git Commands

8.1 Viewing Detailed History

```
# View detailed log with file changes
git log --stat

# View graphical representation
git log --graph --oneline --all

# View commits by specific author
git log --author="Your Name"

# View commits in date range
git log --since="2023-08-01" --until="2023-08-31"
```

8.2 Comparing Versions

```
# Compare two commits
git diff commit1..commit2

# Compare current version with specific commit
git diff HEAD~3

# Compare specific files between commits
git diff HEAD~1 scripts/temperature_analysis.R
```

8.3 Reverting Changes

```
# Undo changes in working directory
git checkout -- filename.R

# Undo last commit (keep changes)
git reset --soft HEAD~1

# Undo last commit (discard changes)
git reset --hard HEAD~1
```

Warning: Be careful with `--hard` reset as it permanently deletes changes!

Step 9: GitHub Features Common for Academic Work

9.1 Using Issues for Project Management

1. Go to your GitHub repository
2. Click "Issues" tab
3. Click "New issue"
4. Create issues for different analysis tasks:
    - "Download and process Landsat data"
    - "Implement temperature calculation algorithm"
    - "Create heat island visualization"

9.2 Using GitHub for Documentation

Create comprehensive documentation:

```
# Create documentation files
mkdir docs
touch docs/methodology.md
touch docs/results.md
touch docs/conclusions.md
```

9.3 Making Your Repository Citation-Ready

Add citation information:

```
touch CITATION.cff
```

Add citation content:

```yaml
cff-version: 1.2.0
message: "If you use this software, please cite it as below."
authors:
  - family-names: "Your Last Name"
    given-names: "Your First Name"
    orcid: "https://orcid.org/0000-0000-0000-0000"
title: "Urban Heat Island Analysis"
version: 1.0.0
date-released: 2023-12-01
url: "https://github.com/yourusername/urban_heat_island_analysis"
```

Step 10: Reproducibility Best Practices

10.1 Creating a Complete Reproducible Environment

Document your R environment:

```
touch scripts/setup_environment.R
```

Add environment setup code:

```
# Setup Environment for Urban Heat Island Analysis
# GG3209 - Spatial Data Science

# Install required packages
required_packages <- c(
  "sf",           # Spatial data handling
  "terra",        # Raster data processing
  "ggplot2",      # Plotting
  "dplyr",        # Data manipulation
  "leaflet",      # Interactive maps
  "RColorBrewer", # Color palettes
  "rmarkdown"     # Report generation
)

# Install missing packages
new_packages <- required_packages[!(required_packages %in% installed.packages()[,"Package"])]
if(length(new_packages)) install.packages(new_packages)

# Load all packages
lapply(required_packages, library, character.only = TRUE)

# Print session info for reproducibility
sessionInfo()
```

10.2 Creating Analysis Workflows

Document your complete workflow:

```
touch scripts/main_analysis.R
```

Add workflow documentation:

```
# Main Analysis Workflow
# Run this script to reproduce the complete analysis

# Step 1: Setup environment
source("scripts/setup_environment.R")

# Step 2: Data preprocessing
source("scripts/data_preprocessing.R")

# Step 3: Temperature analysis
source("scripts/temperature_analysis.R")

# Step 4: Create visualizations
source("scripts/create_maps.R")

# Step 5: Generate report
# rmarkdown::render("docs/final_report.Rmd")

cat("Analysis complete! Check the outputs/ folder for results.\n")
```

10.3 Version Control for Reproducibility

```
# Commit your reproducible workflow
git add scripts/setup_environment.R
git add scripts/main_analysis.R
git commit -m "Add reproducible analysis workflow

- Created environment setup script
- Added main analysis workflow
- Documented all required packages
- Added session info for reproducibility"
```

```
git push origin main
```

Common Git Commands Reference

Essential Commands

Command	Purpose	Example
`git status`	Check current status	`git status`
`git add`	Stage changes	`git add filename.R`
`git commit`	Save changes	`git commit -m "message"`
`git push`	Upload to GitHub	`git push origin main`
`git pull`	Download from GitHub	`git pull origin main`
`git log`	View history	`git log --oneline`
`git diff`	View changes	`git diff filename.R`

Configuration Commands

Command	Purpose	Example
`git config --global user.name`	Set name	`git config --global user.name "John Doe"`
`git config --global user.email`	Set email	`git config --global user.email "john@example.com"`
`git remote add origin`	Add remote	`git remote add origin https://github.com/user/repo.git`

Troubleshooting Common Issues

Issue 1: "Permission denied" when pushing

Solution: Check your GitHub authentication

```
# For HTTPS (recommended)
git remote set-url origin https://github.com/username/repository.git

# Enter your GitHub username and personal access token when prompted
```

Issue 2: "Your branch is behind" message

Solution: Pull the latest changes first

```
git pull origin main
# Then push your changes
git push origin main
```

Issue 3: Accidentally committed large files

Solution: Remove from tracking

```
# Remove file from git but keep local copy
git rm --cached large_file.tif

# Add to .gitignore
echo "large_file.tif" >> .gitignore

# Commit the changes
git add .gitignore
git commit -m "Remove large file from tracking"
```

Issue 4: Want to undo the last commit

Solution: Use reset

```
# Keep changes but undo commit
git reset --soft HEAD~1

# Discard changes and undo commit (be careful!)
git reset --hard HEAD~1
```

Additional Resources

Official Documentation

- Git Documentation
- GitHub Guides

Spatial Data Science with Git

- Happy Git and GitHub for the useR
- Version Control for Scientific Research

Academic Resources

- Software Carpentry Git Lesson
- Pro Git Book (free online)

This guide was created for the GG3209 Spatial Analysis with GIS students at SGSD University of St Andrews. For questions or suggestions, please create an issue in this book repository. 2025

Lab No 1: Intro to Python

Overview

Welcome to the second part of the module of GG3209 Spatial Analysis with GIS. This part will take advantage of the initial part, which provided you with a solid understanding of spatial data formats (vector-raster) and use them to perform multiple types of analysis like the so-called Multi-Criteria Evaluation (MCE) using the widely popular Open-Source GIS tool, QGIS.

Now, in this part, you will be guided to handle and use another powerful tool in the geospatial field, Python. It is a free and open-sourced scripting language that was commonly used to automate tasks in the GIS world. Nowadays, it is one of the most popular programming languages[1], especially in GIScience. It is widely used in the private and public sectors and academia for cutting-edge research, where scripts are created and shared using this language to share new methods, knowledge, data, and analysis through multiple scientific fields.

In fact, most companies or institutes where you might want to apply will be happily interested in your development skills using Python and will validate your current contribution or work in platforms like GitHub, where you can share and disseminate your coding project. Think about its impact as we cluster R for spatial statistical analysis, and Python is mainly used for escalable and robust spatial analysis. Every day, more packages[2] and code repositories are shared and maintained for easy use and installation, allowing developers or analysts from all backgrounds and expertise to use and integrate them into their own code.

This part of the module and this lab workbook are meant to be an introduction to Python. As with any new language, you need to learn the basic rules (grammar) to write your own script, and then, with practice and more practice, you will soon become a Python developer.

[1] https://www.stackscale.com/blog/most-popular-programming-languages/

[2] https://pypi.org/

> Do not be afraid of failure or errors, even during the installation process; it has happened to all of us, regardless of the level of expertise or number of projects created. In programming, failure is part of the process; what is essential is to find the foundation of any issue and understand how code, logic, and syntax work in harmony to get the results you are expecting.

Estimated time of completion: 45 Minutes

Learning Outcomes

- Run Python scripts using **ArcGIS Pro** and **ArcGIS Online**
- Conducted xgeoprocessing tasks (e.g., buffering, proximity analysis)
- Created and saved notebooks and web maps
- Practiced using both ArcPy and ArcGIS Python API

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Lab No 1: Introduction to Python using ArcGIS Online

Perhaps one of the fastest and easiest way to start with python as spatial data scientists for you is to create a notebook in ArcGIS Pro and use it to run some Python code. In here you don't need to install any python environment as everything comes as part of the installation of ArcGIS Pro. We will work this way, so you are familiar with python and then we will move to more advance instructions later.

Setting up the ArcGIS Pro Project

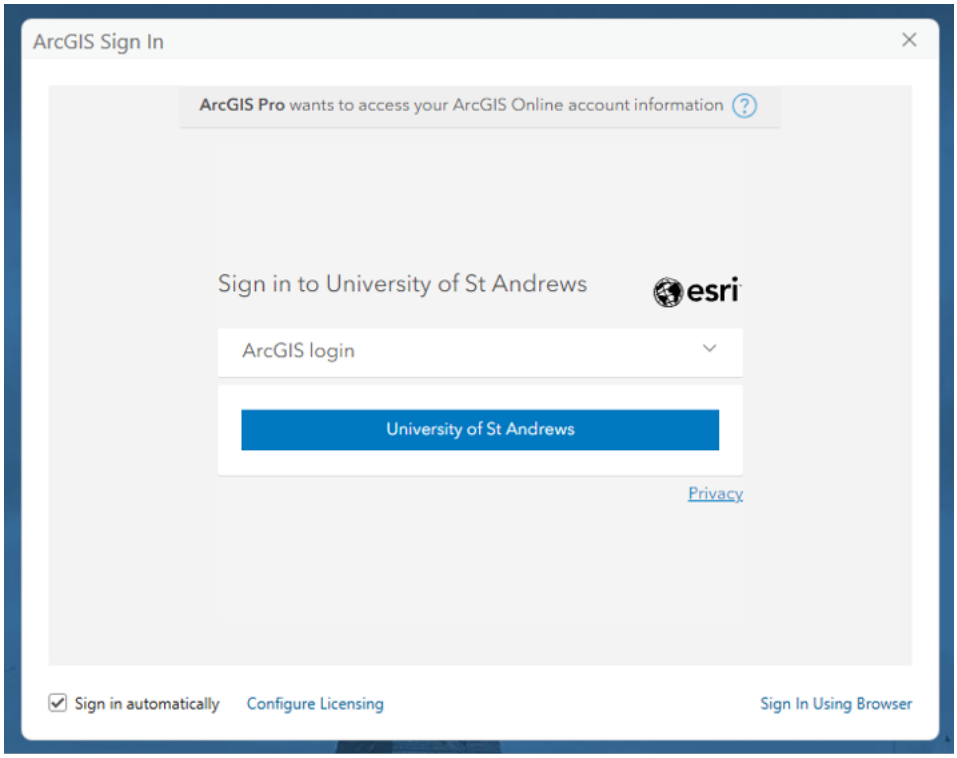
1. In Moodle download the file **PY4SA_Week5.ppkx** in PY4SA Lab Week 5 to a location on your lab computer.

   The file contains an ArcGIS Pro package that includes, maps, a database combined.

   In this lesson the data is shown at specific folder. You can use a different folder, but be sure to adjust the paths in the instructions that follow.

2. Find the **PY4SA_Week5.ppkx** file (likely in the Downloads folder), and double click to open it using ArcGIS Pro.

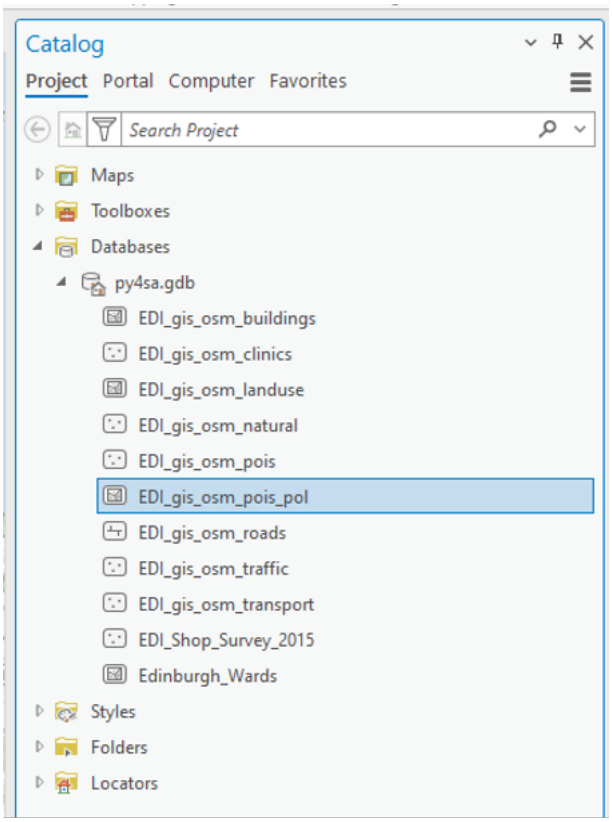
3. ArcGIS Pro will probably ask you to sign In, click in the blue button **University of St Andrews** to authenticate using your university credentials.



4. Add your university email and password. And then let ArcGIS Pro start and unpack the **PY4SA_Week5** project
5. The project loads a map called **PY4SA_Starting_with_Python** showing the **Edinburgh Wards** and **trees** from Open Street Map, you can see more and more details when you zoom in to the map, take a sort time to familiarise yourself with the data and the map. You will add other **feature classes** (the ArcGIS version of a Shapefile) to this map.

Accessing the Catalogue Pane

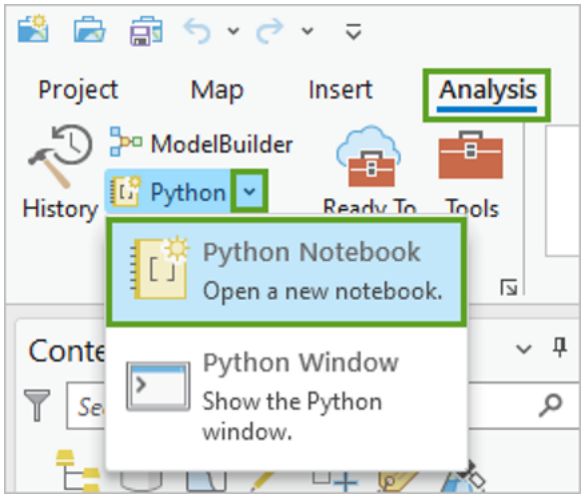
6. If the **Catalog** pane is not already visible, click the **View** tab and click **Catalog Pane**.
7. Dock the **Catalogue** pane to the right of the map.
8. Expand **Databases** folder and then **py4sa.gdb** geodatabase.



The **geodatabase** contains several **feature classes**, including spatial data from Open Street Map (OSM) and the Edinburgh Open Data Geo Portal.

Creating a Python Notebook

9. On the ribbon, click the **Analysis** tab, and in the **Geoprocessing** group, click the drop-down arrow for the **Python** button and click **Python Notebook**.



Clicking the **Python** button also opens a new notebook, but the drop-down menu allows you to see that you have a choice between **Python Notebook** and **Python Window**. The **Python Window** is another way to run Python code in ArcGIS Pro.

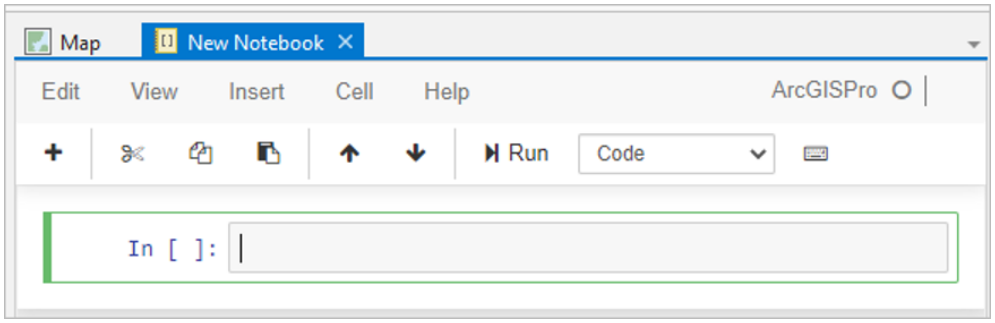
It may take a moment for the new notebook to appear, and you may see the message **Initialising Kernel** on the screen while you wait. This means ArcGIS Pro is getting ready to run code in the notebook. The kernel is software that runs in the background to execute the Python code you enter in the notebook. **Do not panic!**

Once the notebook opens, it appears as a new tab in the main window of ArcGIS Pro.

The new notebook is stored as an **.ipnyb** file in your project home folder. The new notebook also appears under the **Notebooks** folder in the **Catalog** pane.

Running Your First Python Code

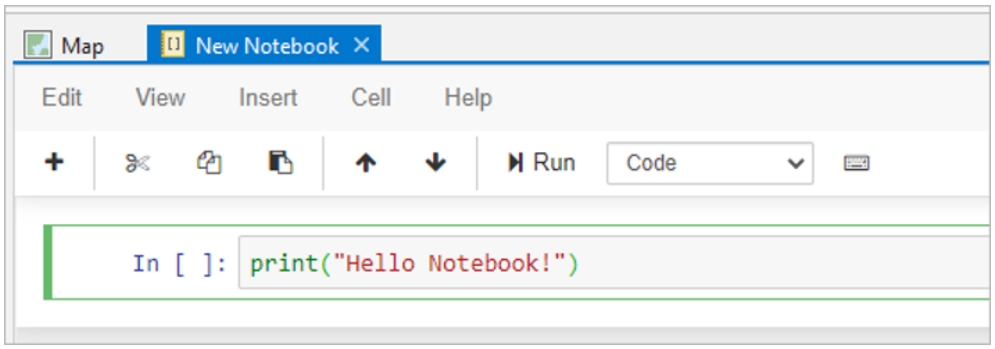
10. Click inside the empty cell in the notebook.



The outline turns green.

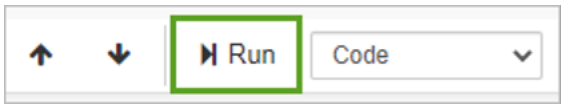
11. Type the following line of code:

```
print("Hello Notebook!")
```

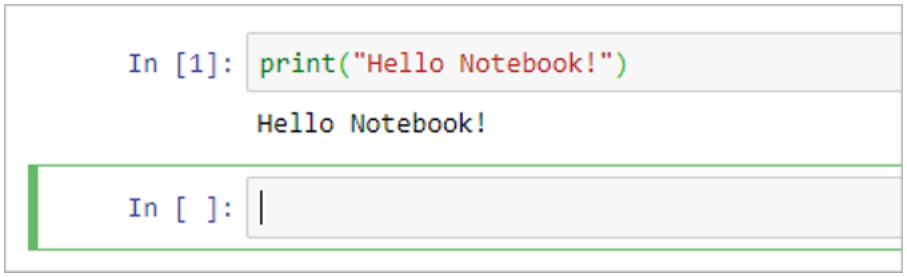


This code calls the print function on a single input parameter within the parentheses. This parameter is a string because it is enclosed in quotation marks. Strings are an important and useful type of data that you can work with in Python.

12. On the toolbar above the cell, click the **Run** button.



The code in the cell is run and the result is printed below the cell. The print function runs on the string value "Hello Notebook!" and prints it. The quotation marks are not printed, because they are not part of the string—they only identify it as a string. The number 1 appears in the brackets to the left of the cell. A new empty cell is added below.



You can also run the currently selected cell by pressing **Ctrl+Enter.**

You can add multiple lines of code within a single cell by pressing the Enter key after each line. This may be counterintuitive if you are used to running

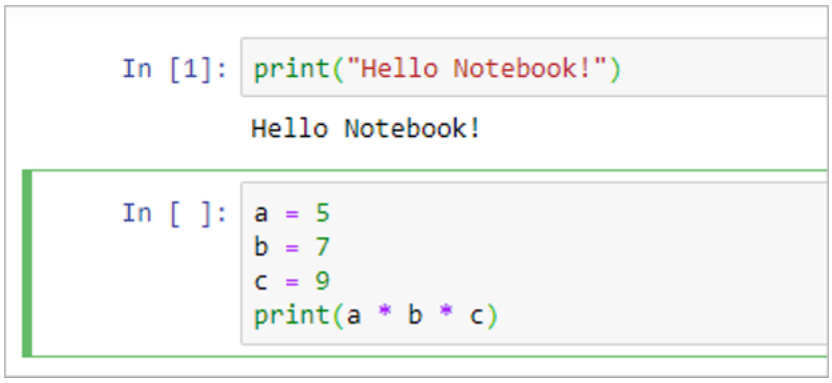
code in the Python window or in the interactive window of a Python editor, where pressing the Enter key results in running the line of code.

Working with Variables

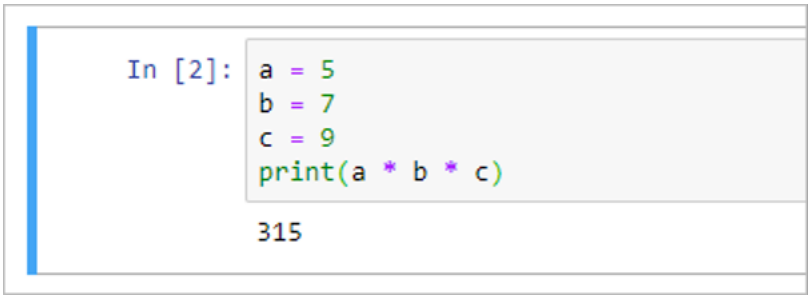
13. In the cell below your **Hello Notebook!** code, type the following lines of code:

```
a = 5
b = 7
c = 9
print(a * b * c)
```

This code creates three variables, **a**, **b**, and **c**, and assigns their values to be equal to the numbers **5**, **7**, and **9**. The last line prints the result of multiplying the variables.

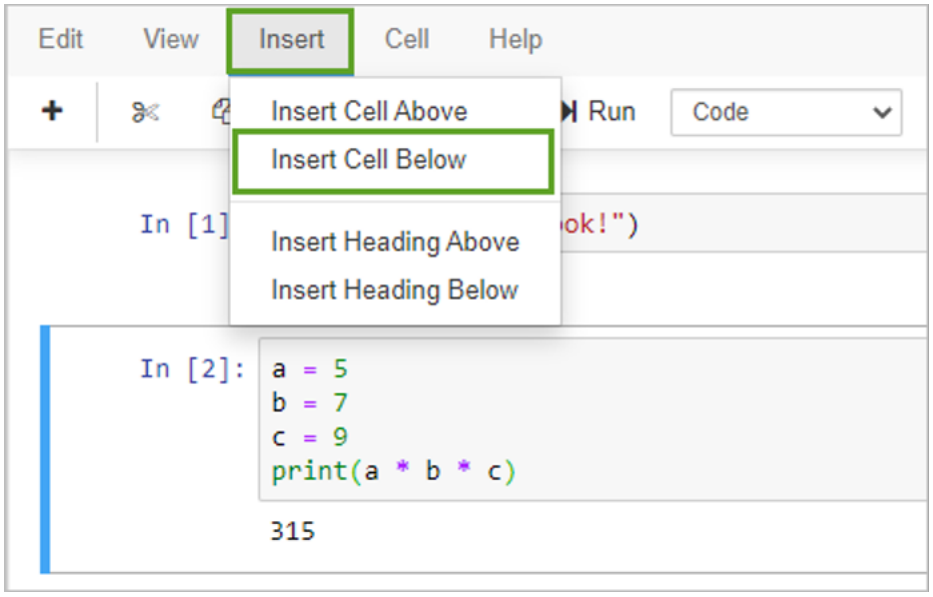


14. Press Ctrl+Enter.



After the cell runs, the value **315** appears below it. The number **2** appears in brackets to the left of the cell to indicate that this is the second cell run.

15. At the top of the notebook, click the **Insert** menu, and click **Insert Cell Below**.



A new cell is added below the currently selected cell.

16. In the new cell, type the following line of code:

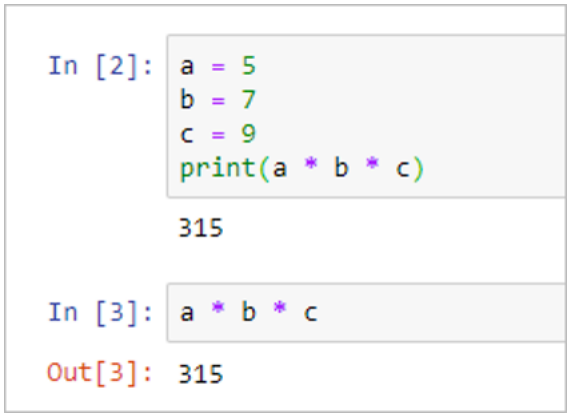
```
a * b * c
```

What do you think this will do when you run the cell?

17. Run the cell and look at the result.

Did the result match your expectation?

The values of the variables **a**, **b**, and **c** are stored in memory after you set them, so you can use them in another cell.



The result of multiplying the values stored in **a**, **b**, and **c** is printed when you run the cell.

The print statement is not required because in a notebook, the Python window, and in the Python interpreter, Python evaluates simple expression statements and prints their value.

Understanding Variable Scope and Errors

18. If you ran the cell by pressing **Ctrl+Enter**, insert a new cell below it.

    If you ran the cell by pressing the run button, there should already be a new cell below it.

19. In the new cell, type the following line of code:

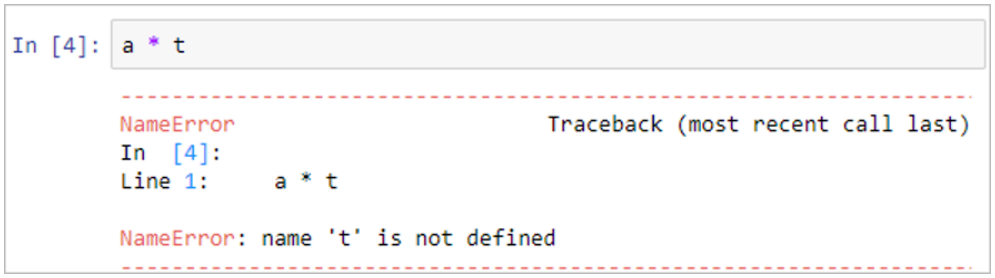
```
a * t
```

    What do you think this will do when you run the cell?

20. Run the cell and look at the result.

    Did the result match your expectation?

    Variable a has been set to the numeric value of 5, but the new variable t hasn't been set yet. This causes an error. In Python, you can't use variables until you assign their values.



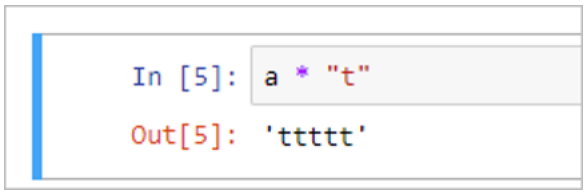
21. Edit the code in the cell as follows:

```
a * "t"
```

    What do you think this will do when you run the cell?

22. Run the cell and look at the result.

Did the result match your expectation?



By putting **t** in quotation marks, you have identified it for Python as a string. Python evaluates the expression as the string t five times, resulting in the new string value **'ttttt'**.

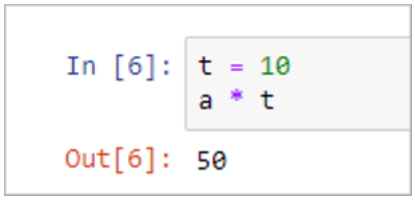
23. Add a new cell and enter the following code:

```
t = 10
a * t
```

What do you think this will do when you run the cell?

24. Run the cell.

Did the result match your expectation?



Because the first line in the cell defined the variable **t** as being equal to the number **10**, Python was able to multiply it by the value stored in the variable **a**.

Sum-up: You've opened a new notebook in ArcGIS Pro and added and run some basic Python code. Next, you will use notebook functions to manage the code in the cells.

Manage code in cells

The code in Notebooks is run in cells. The order in which cells are run is indicated by the numbers beside the cells after they are executed. Notebooks have tools to manage cells. Now you'll explore these aspects of working with Python in a notebook.

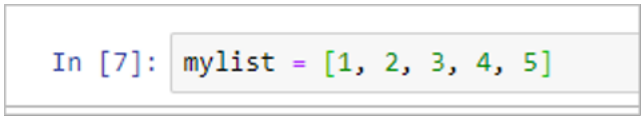
Working with Lists

1. In the next empty cell (add a new one if you need to), type the following line of code and run the cell.

```
mylist = [1, 2, 3, 4, 5]
```

   What happened?

   This code defined a new variable and set its value, but did not print anything.

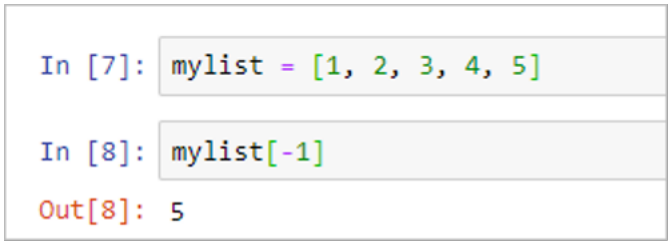


   The variable **mylist** is a list, as indicated by the square brackets. Lists are an important data type in Python that consist of a sequence of elements. In this case, those elements are numbers, but lists can also contain other types of data. Elements in a list are separated by commas.

2. In the next empty cell, type the following code and run the cell.

```
mylist[-1]
```

   What happened?



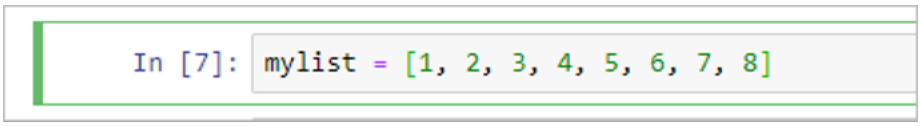
   Elements in a list are indexed, starting with index number zero. You can retrieve specific elements in a list by using their corresponding index numbers. Index number -1 means the first element starting from the end of the list—in other words, the last element. This returns the number **5**.

   As you have seen, the cell input and output prompts show a number after the cell has been run. This number starts at 1 and increases for additional cells. The number increases every time you run a cell, including when you rerun a previously executed cell. The numbers help you keep track of the order in which the cells were run.

Understanding Cell Execution Order

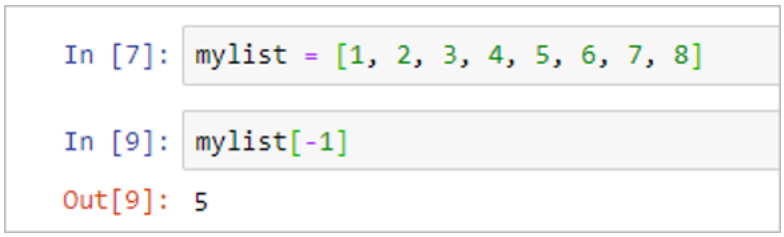
3. Change the code in the cell defining the **mylist** variable to the following by adding more elements, but don't run the cell.

```
mylist = [1, 2, 3, 4, 5, 6, 7, 8]
```



4. Click the cell below this one, with the code `mylist[-1]` and click the **Run** button.

   Does what happened match what you expected?



   The result is the number **5**. Why isn't it the number **8**?

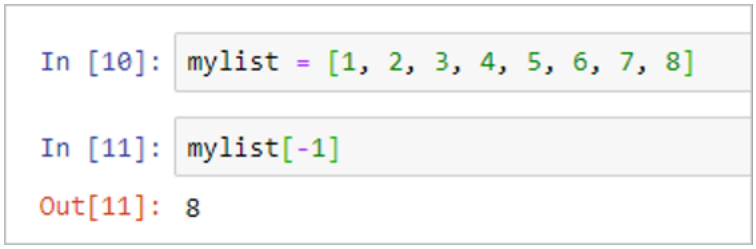
   Code in a notebook is entered cell by cell and any previously used variables are stored in memory.

   Until you run the cell with the code that redefines the **mylist** variable, the value of **mylist** is still the value stored in memory, **[1, 2, 3, 4, 5]**, and the value at position -1 in that list is still **5**.

5. Click the cell with `mylist = [1, 2, 3, 4, 5, 6, 7, 8]` and run it.

6. Click the cell with `mylist[-1]` and run it.

   Now the value in the last position of the list is **8**.



An alternative to running individual cells is to select multiple cells and run them together, or to run all the cells in a notebook by clicking the **Cell** menu and clicking **Run All**.

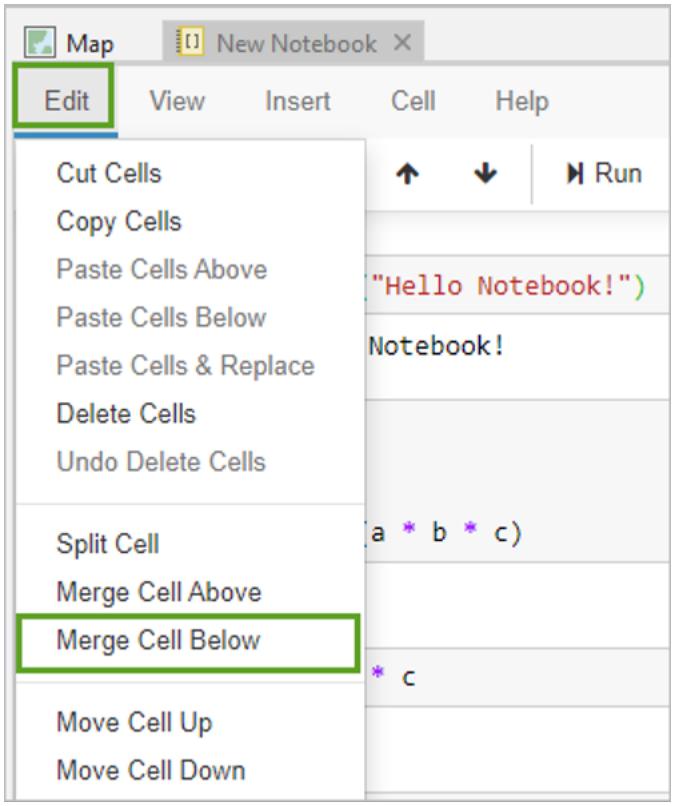
It is a good practice to organise lines of code that belong together in the same cell. For example, it would make sense to combine the two previous cells into a single cell. You can manually copy and paste code from one cell to another, but you can also combine cells.

Merging Cells

7. Click the cell that defines the **mylist** variable.

   That cell has `mylist = [1, 2, 3, 4, 5, 6, 7, 8]` in it.

8. Click the **Edit** menu and click **Merge Cell Below**.



The result is a single cell with the combined lines of code. The results below the cells have been removed. An empty line is added between the lines of code from the two merged cells, but you can edit the cell to remove it if you want.

9. Run the merged cell.

```
In [12]: mylist = [1, 2, 3, 4, 5, 6, 7, 8]

         mylist[-1]

Out[12]: 8
```

The **Edit** menu provides many other useful ways to manipulate the cells in your notebook. You can copy and paste cells, delete them, split and merge them, and move a selected cell up or down relative to the other cells.

Additional tools are available under the **View**, **Insert**, and **Cell** menu options.

Some of the most widely used tools are also available as buttons on the notebook toolbar.

These include the following:

- **Insert cell below**
- **Cut selected cells**
- **Copy selected cells**
- **Paste cells below**
- **Move selected cells up**
- **Move selected cells down**

More tools can be found on the **Command Palette**.

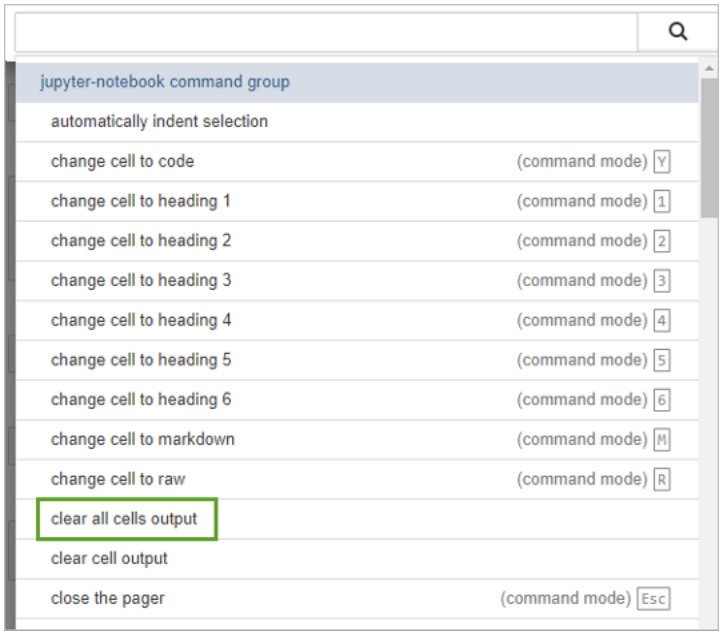
Using the Command Palette

10. Click the **Command Palette** button.

A list of commands appears.

You can run a command by clicking it. The command is applied to the selected cells in the notebook, or to all cells, depending on the command.

11. In the **Command Palette**, click **clear all cells output**.

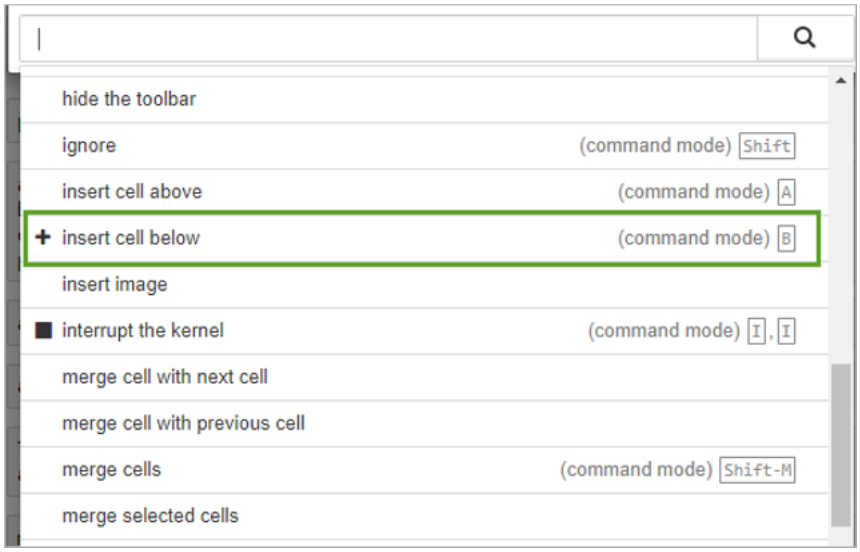


All code remains the same, but all outputs have been removed. The input and output prompts are blank, since none of the cells have been run. When you run a cell, the prompts start again at 1.

The **Command Palette** also show shortcuts for many of the tasks.

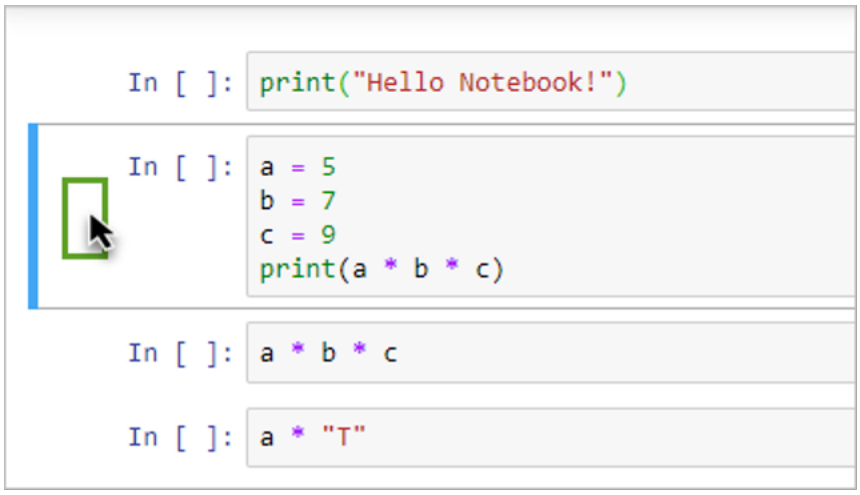
Keyboard Shortcuts

12. Click the **Command Palette** button and scroll down to **insert cell below**.



The keyboard shortcut for this command is listed to the right of it. The shortcut is the letter B when the notebook cell is in command mode.

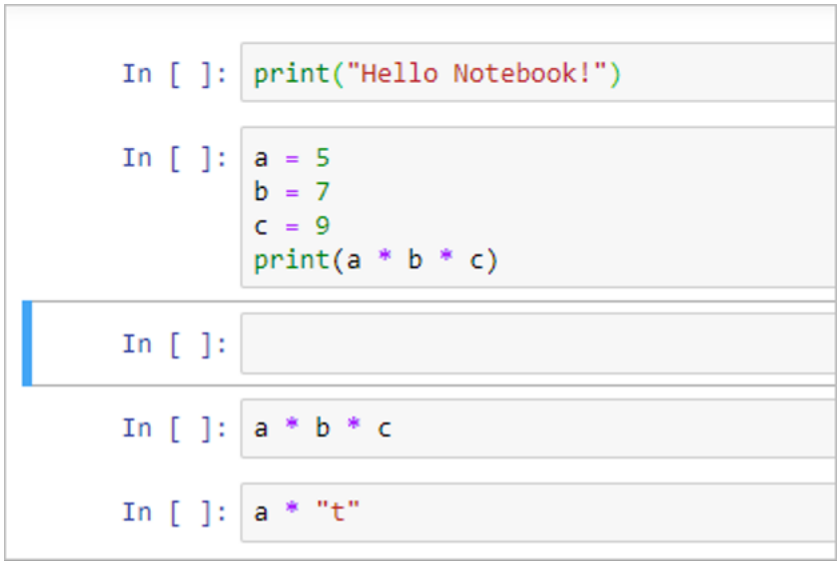
13. Hide the **Command Palette** by clicking outside of the palette but inside the notebook.
14. Click the space to the left of the second cell, so it turns blue.



Be sure not to click inside the code section, which will turn the cell green.

The cell border is blue to indicate that it is in command mode.

15. Press the B key on your keyboard.



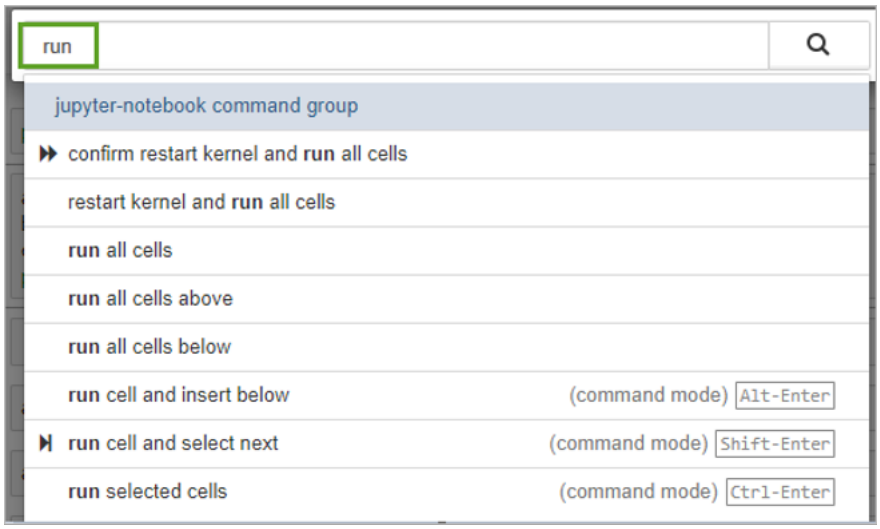
A new cell is inserted below the selected cell. If the cell had been green, you would add the letter b to the code in the cell.

These shortcuts are not case sensitive, so b and B are the same.

There is no need to memorise these commands, but experienced coders memorise and use some of them to speed up their work. For most basic tasks, the buttons and menu options in the notebook work well.

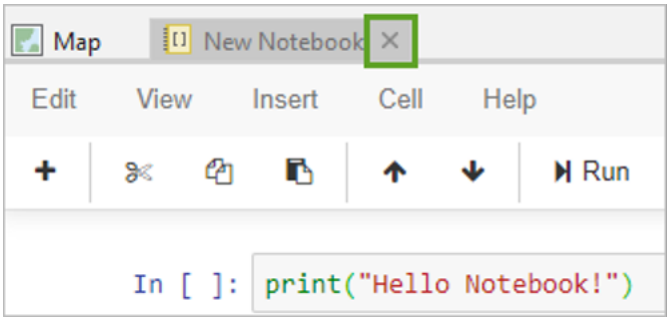
If you are looking for the command for a specific task, you can search for it by using the search bar at the top of the **Command Palette**.

16. Open the **Command Palette** and type run in the **Search** box.



This filters the list to the tools with run in their name. Some commands have a shortcut. For example, the shortcut for **run selected cells** is Ctrl +Enter.

17. Hide the **Command Palette** by clicking outside of the palette but inside the notebook.
18. Close the notebook.



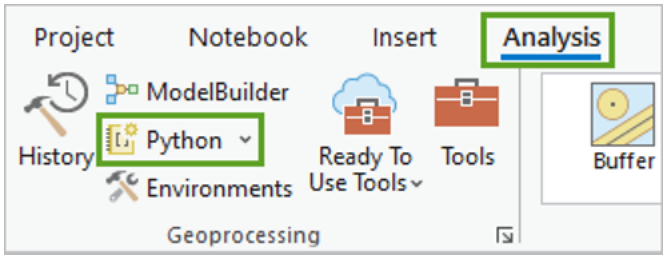
You've seen how to enter and edit Python code in notebook cells, and how to interact with the notebook to run and manage the code. Next, you'll use a notebook to run geoprocessing tools in ArcGIS Pro.

Run geoprocessing tools in a notebook

Now that you've had some practice entering code in a notebook, it is time to use some geoprocessing tools. You will start with a new notebook.

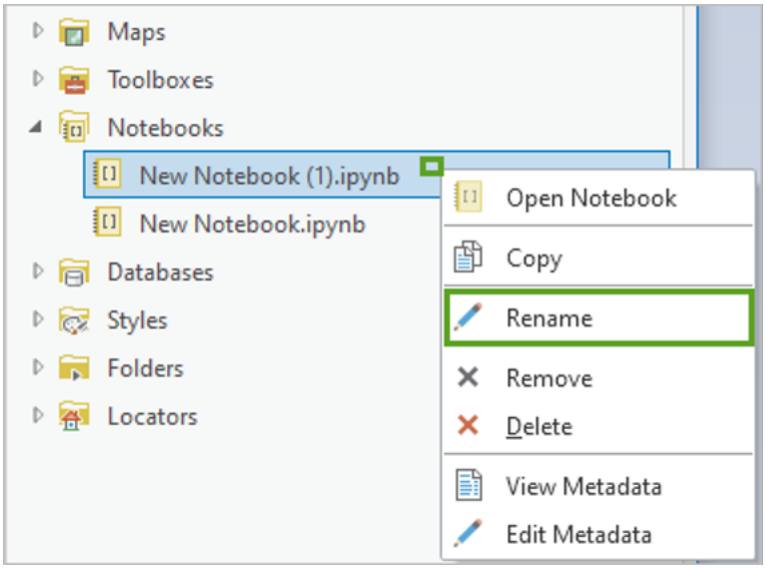
Creating a New Notebook for Geoprocessing

1. Click the **Analysis** tab, and in the **Geoprocessing** group, click **Python**.



   The new notebook opens.

2. In the **Catalog** panel, expand the **Notebooks** section.
3. Right-click the new notebook, **New Notebook (1).ipynb**, and click **Rename**.

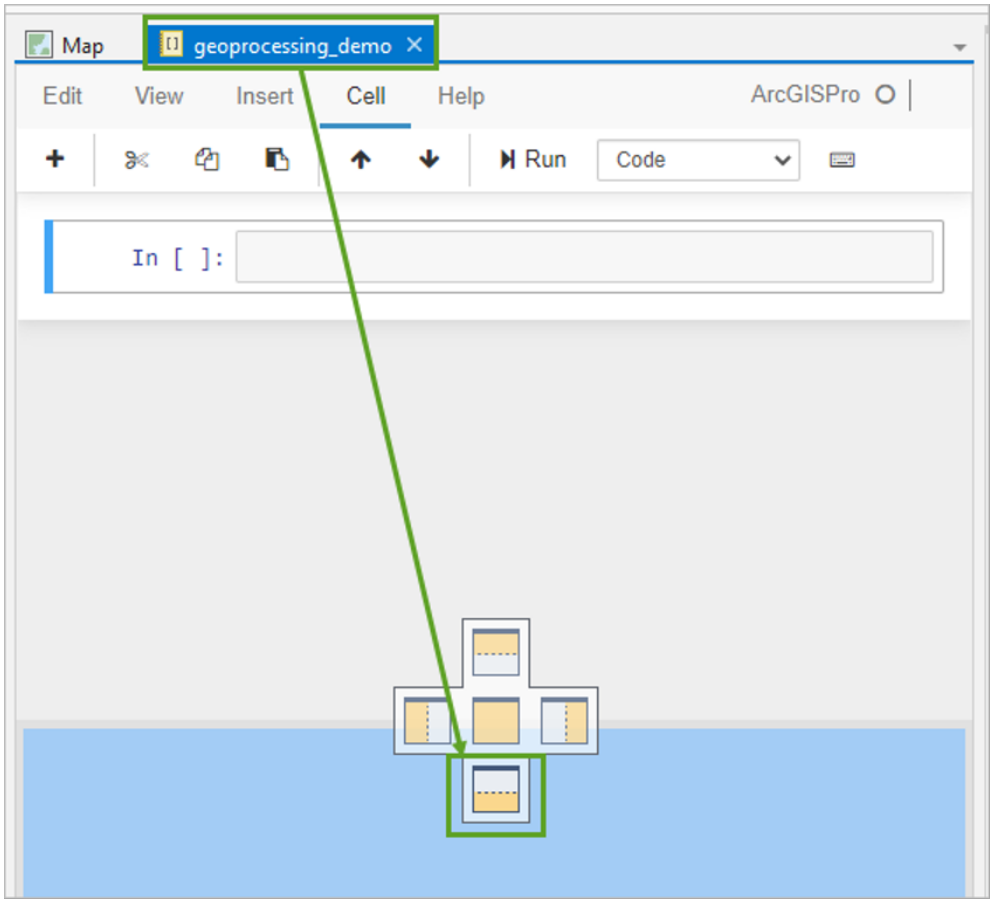


4. Type `geoprocessing_demo` and press Enter.

   The new notebook is renamed. In the **Catalogue** pane, you can see that the .ipynb file extension was automatically added to the name. The notebook tab now says **geoprocessing_demo**.

   For the next steps, it is useful to see the map and the notebook side by side.

5. Drag the **geoprocessing_demo** notebook tab to the docking target that appears below.



   The notebook is docked below the map. Now you'll be able to see the results of your code as you use Python in the notebook to work with feature classes on the map.

Importing ArcPy and Running Geoprocessing Tools

6. In the empty cell, type the following line of code and run the cell:

```
import arcpy
```

This line of code imports the ArcPy package. ArcPy is a Python package that makes much of the functionality of ArcGIS Pro available from within Python, including geoprocessing.

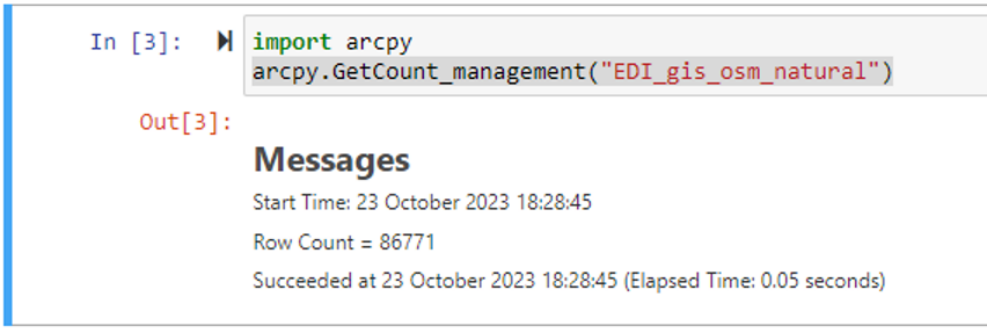
Since you are using this notebook in ArcGIS Pro, code that uses geoprocessing tools will not produce an error if you have not imported ArcPy. However, it is good practice to always include `import arcpy` at the top of your geoprocessing code so it will also work when run outside of ArcGIS Pro.

7. In the same cell, add a new line and type the following code:

```
arcpy.GetCount_management("EDI_gis_osm_natural")
```

This code uses ArcPy to run the **Get Count** tool to determine the number of features in the **EDI_gis_osm_natural** feature class.

8. Run the cell.

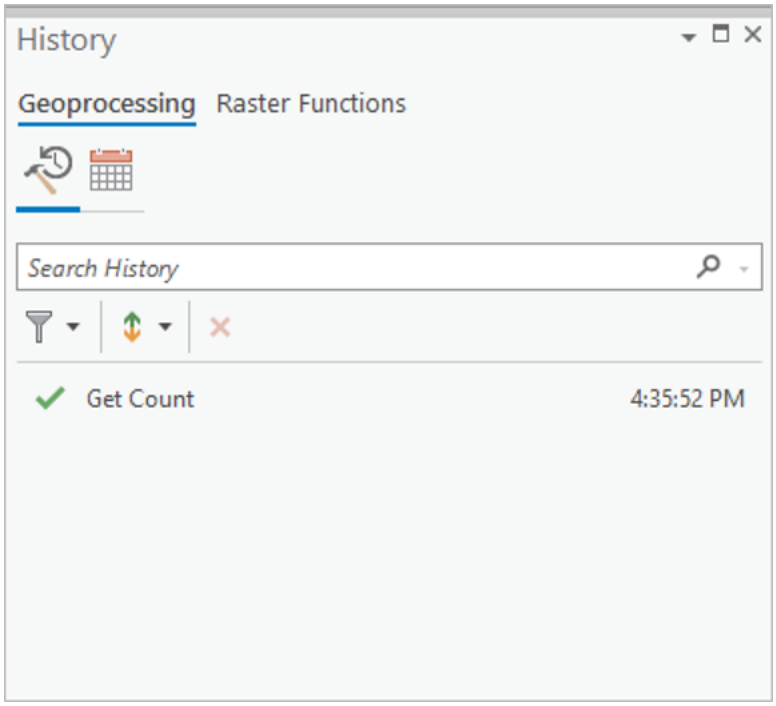


GetCount is a function of ArcPy that runs the **Get Count** geoprocessing tool located in the **Data Management Tools** toolbox.

The result appears below the code cell. There are 86771 rows (features) in the feature class. These results are very similar to the messages you see after running a tool using the tool dialogue box in ArcGIS Pro. Notebooks are integrated in the geoprocessing framework of ArcGIS Pro. This means that running a tool in a notebook is like running a tool using the tool dialogue box. Any tool that you run in a notebook also appears in the **History** panel.

9. Click the **Analysis** tab and click **History**.

The tool appears in the geoprocessing history.



10. Close the **History** panel

Understanding File Paths and Workspace

11. Edit the `arcpy.GetCount` code line to the following:

```
arcpy.GetCount_management("EDI_gis_osm_building")
```

12. Run the cell. Are you getting any errors?

    In case this code fails with an error message. At the end of the message, the following information appears:

    ExecuteError: Failed to execute. Parameters are not valid.

    ERROR 000732: Input Rows: Dataset EDI_gis_osm_building does not exist or is not supported

    Failed to execute (GetCount)

    Why do you think the code failed, when the code to get the count of natural features worked?

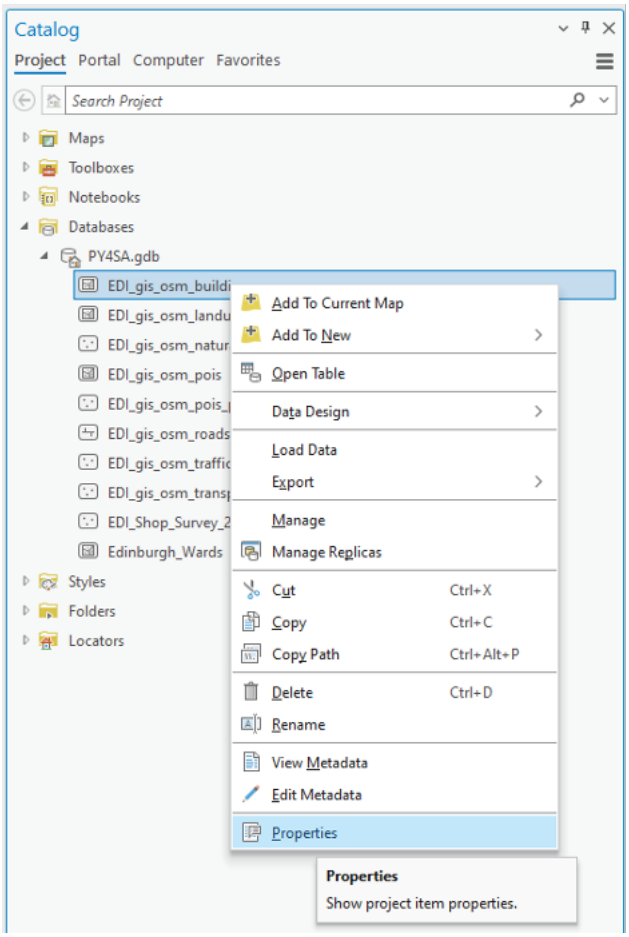
    The **EDI_gis_osm_natural** feature class is a layer on the active map. In a notebook, you can refer to a dataset by the name of the layer in the active

map, like you can when you run a geoprocessing tool interactively using its graphical user interface.

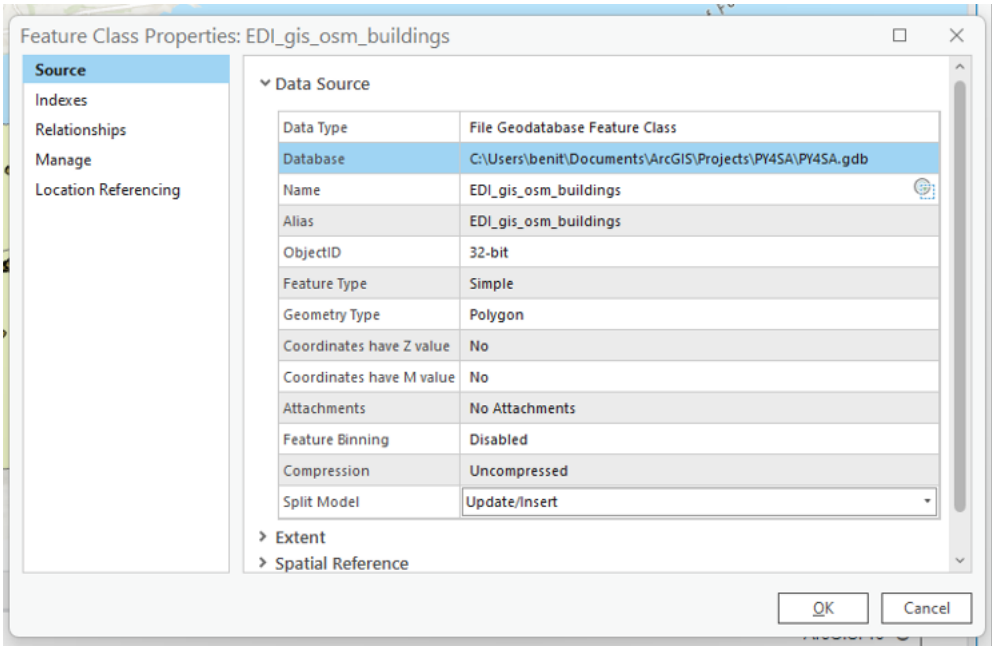
The **EDI_gis_osm_building** feature class is not present as a layer in the active map, and it is also not a feature class in the default geodatabase for the project. You can refer to a feature class that is not in the active map or the default geodatabase by specifying its full path.

Next, you'll look up the path to the **EDI_gis_osm_buildings (this layer does exist)** feature class. The path where the data is located is a key aspect in Python, so now let's explore how you can know where the data is stored and then use the correct path in your scripts.

13. In the **Catalog** pane, expand the **Databases** section and expand **PY4SA.gdb**.
14. Right-click **EDI_gis_osm_buildings** and click **Properties**.



15. Click the column next to **Database** and select the full path to the geodatabase.



16. Right-click the selected path and click **Copy**, and then close the **Properties** dialog box.

    The path in this example is as follows:

    `C:\Users\benit\Documents\ArcGIS\Projects\PY4SA\PY4SA.gdb`

    The path on your computer will be different, depending on where and how you unzipped the .zip file with the data. You may not have put the data in a folder on your drive C, or inside a folder named Lessons, for example. You should use the path on your computer in the next step.

17. Click in the notebook cell and update the path that you copied. But make sure you add a backslash \ between the path you copy and the name of the feature class.

```
arcpy.GetCount_management("C:\Users\benit\Documents\ArcGIS\Projects\PY4SA\PY4SA.gdb\EDI_
```

18. Click immediately after the open parenthesis and before the first quotation mark, and type the letter **r**.

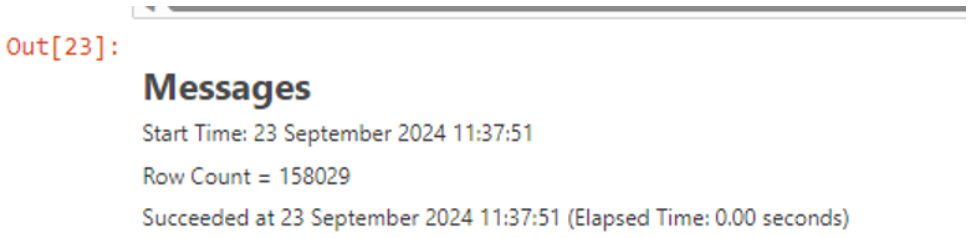
```
arcpy.GetCount_management(r"C:\Users\benit\Documents\ArcGIS\Projects\PY4SA\PY4SA.gdb\EDI
```

    You need to add the letter **r** to tell Python that this path is a raw string. Windows computers use the backslash character as a path separator. In Python, the backslash character is an escape character that, when next to some other characters in a string, encodes tab, new line, or other special characters. This means that where `\N` occurs beside `\NotebookStart` in the path, Python reads

the string as having a new line character. Placing the r before the string tells Python to ignore the escape characters.

19. Run the cell.

    The **Get Count** tool runs and returns a message that there are 158029 features in the feature class.



    You can also use a forward slash (/) character as a path separator in Python code, or you can double the backslash characters.

    The following are all valid ways of writing this path in Python:

```
r"C:\Lessons\NotebookStart\Toronto.gdb\ambulances"
"C:/Lessons/NotebookStart/Toronto.gdb/ambulances"
"C:\\Lessons\\NotebookStart\\Toronto.gdb\\ambulances"
```

    If you use a forward slash (/) or double backslash (\\) as your path separator, you do not add the r before the path string.

    For someone who is used to Windows paths delimited by backslashes, this can look a little strange at first, but it is important to remember.

    One way to avoid having to specify full paths for tools **is to set the workspace**.

Setting the Workspace

20. Edit the code to add a new line between the two lines beginning with `import arcpy` and `arcpy.GetCount`. Add the following line:

```
arcpy.env.workspace =
```

    This line is setting a property of the environment class, arcpy.env, to be equal to some value. Next, you'll cut the path to PY4SA.gdb and paste it after this code to set the path.

21. Add the path to the PY4SA geodatabase. For example:

```
arcpy.env.workspace = r"C:\Lessons\NotebookStart\PY4SA.gdb"
```

22. Run the cell.

23. To validate the workspace has been properly defined add a new cell and run the following line:

```
arcpy.env.workspace
```

    You should get the path you defined as your workspace in this python environment.

Run an analysis using a notebook

Next, you will do some GIS analysis work using the notebook. Suppose you are interested in finding out what areas within the Edinburgh_Wards are farthest from clinics in Edinburgh. You can use geoprocessing tools in a notebook to identify these areas.

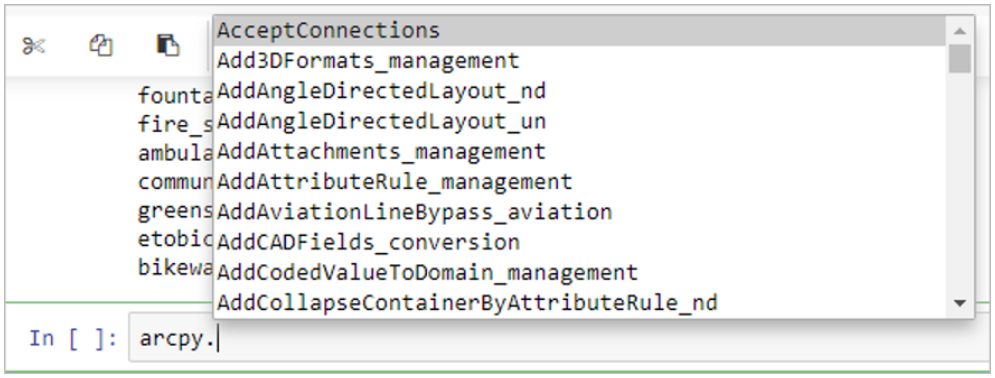
Using Tab Completion and Tool Signatures

1. Add a new cell below the current one.

2. Place the cursor inside the cell and start typing the following:

```
arcpy.
```

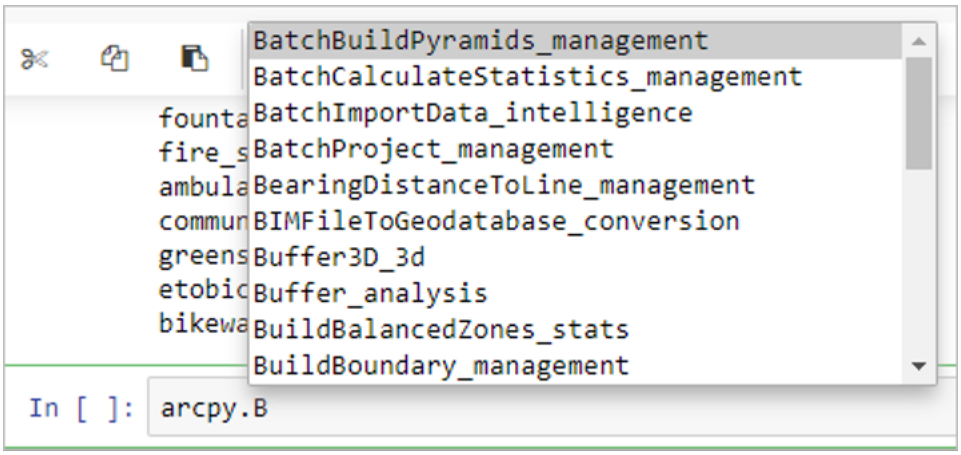
3. Press the Tab key.



    A list of all of the available ArcPy options appears.

    You can scroll down and click an item to select it from this list, or you can continue typing.

4. Type an uppercase B.

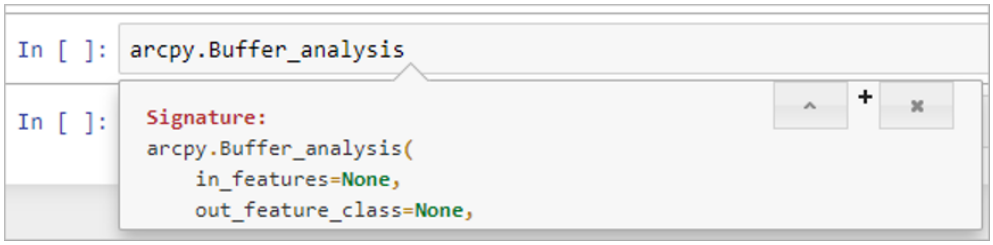


5. Click **Buffer_Analysis**.

   The cell now says `arcpy.Buffer_analysis`.

   This process of beginning to type some code and then pressing the Tab key to see and choose from matching options is called tab completion, and it can help you find and more quickly access the commands you need.

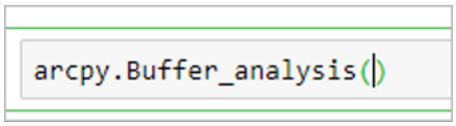
6. With your cursor still at the end of the line of code, press Shift+Tab.



   A window with the syntax hints for the Buffer_analysis tool appears. You can click the arrow button to expand it to read the whole topic.

7. Click the close button to close the **Signature** window.

8. Type an open parenthesis.



   A close parenthesis is also added, and the cursor is placed between them. This is where you can add parameters for the Buffer_analysis tool.

9. Type a quotation mark.

```
arcpy.Buffer_analysis("")
```

   A second quotation mark is added. Python needs strings to be enclosed in quotation marks, so it adds a matching quotation mark, with the cursor between them.

   The three parameters that the Buffer_analysis tool requires are the input feature class, the output feature class, and the buffer distance. There are other optional parameters, but these are the only ones that are required.

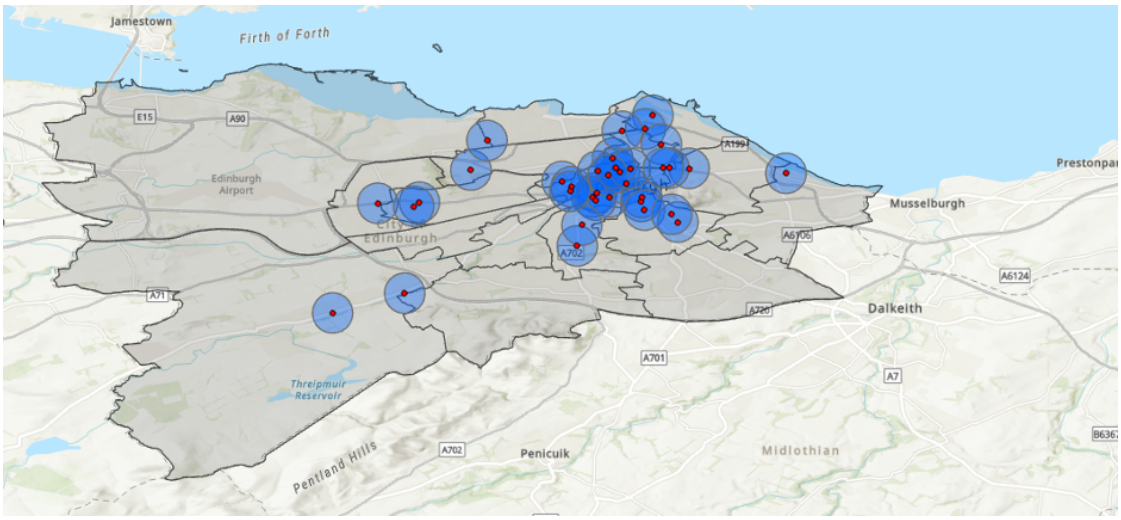
   You'll buffer the **EDI_gis_osm_clinics** feature class, name the output feature class **clinic_buffer**, and make the tool buffer the fire stations by a distance of 1000 meters.

10. Complete the line of code as follows:

```
arcpy.Buffer_analysis("EDI_gis_osm_clinics","clinic_buffer ","1000 METERS")
```

    The three parameters of the tool are strings. The tool is able to locate the **EDI_gis_osm_clinics** feature class using only its name because it is a layer on the map. The tool is able to write an output feature class using only the name "clinic_buffer" because the workspace is set. The tool has logic built in to detect the buffer distance value and the units of measure in the string "1000 METERS".

11. Run the tool.



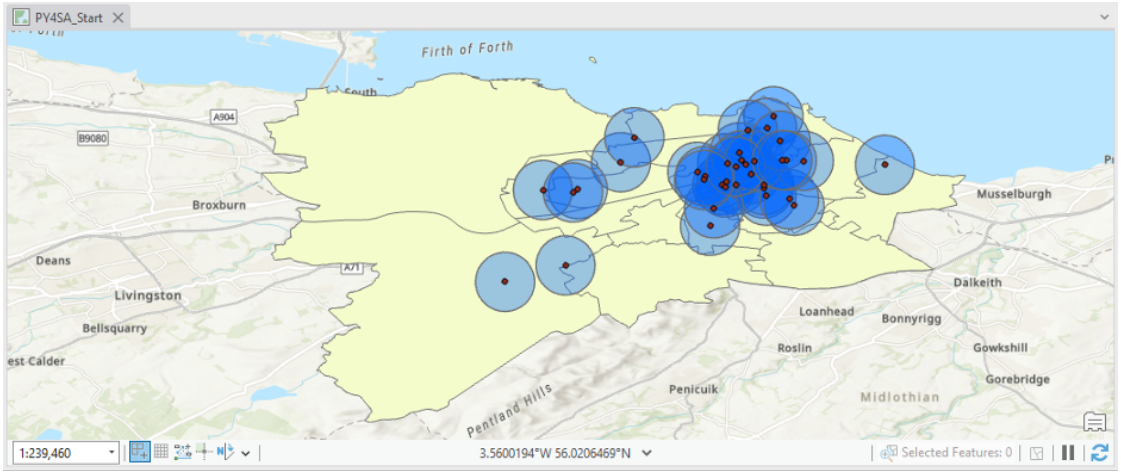
The output features are added to the map.

The results show which areas fall within 1000 meters, or 1 kilometre, of a clinic and which areas do not. **Having both the notebook and the map open at the same time makes it easy to see the results of different choices.**

12. You probably need to hide the ***EDI_gis_osm_natural*** layer and add the **EDI_gis_osm_clinics** to the map, so you can see the buffer areas created around each clinic in Edinburgh.

13. Now, change the buffer distance to 1750 meters and run the cell again.

```
arcpy.Buffer_analysis("EDI_gis_osm_clinics","clinic_buffer","1750 METERS")
```



Note: If you get an error message, "**ExecuteError: Failed to execute. Parameters are not valid**", that mentions that **clinic_buffer** already exists, then your ArcGIS Pro environment settings, geoprocessing options are not set to allow existing feature classes to be overwritten. To fix this issue, insert a new line in the cell before the arcpy.Buffer_analysis line. On the new line, add the following code:

```
arcpy.env.overwriteOutput = True
```

This will allow the **Buffer** tool to overwrite the previous output. The cell should now contain:

```
arcpy.env.overwriteOutput = True
arcpy.Buffer_analysis("EDI_gis_osm_clinics","clinic_buffer","1750 METERS")
```

Run the cell.

The areas outside of these buffers are further away from the clinics, which may increase the time it takes for an ambulance to respond to a call. To find the areas that are affected, rather

than the parts that are not, you will use the erase tool to remove the areas within the buffers from the Edinburgh Wards feature class.

Using the Pairwise Erase Tool

14. Add another cell and enter the following code:

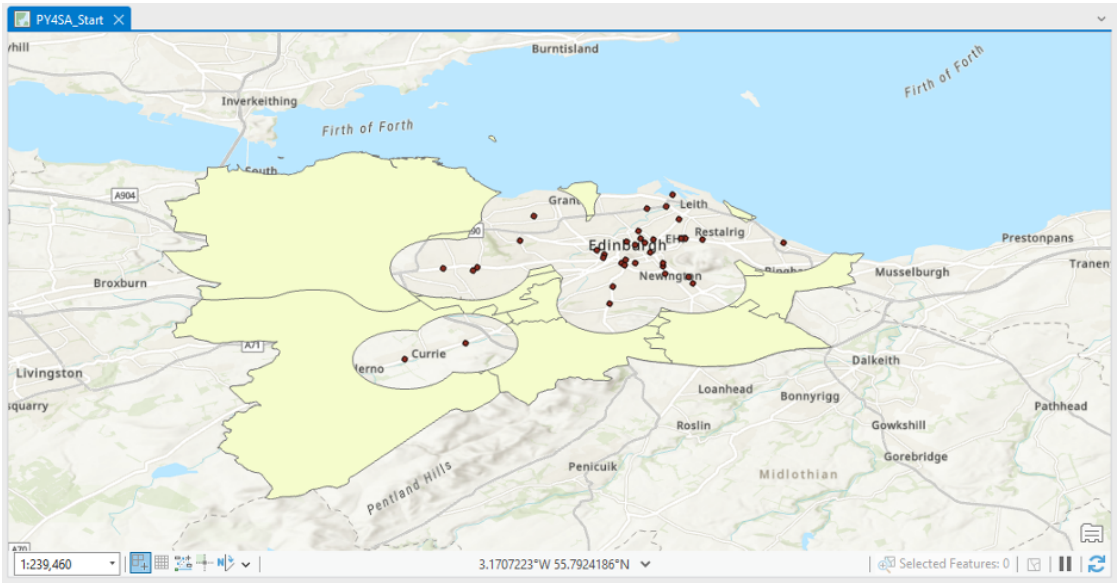
```
arcpy.PairwiseErase_analysis("Edinburgh_Wards", "clinic_buffer", "no_service")
```

    This calls the PairwiseErase_analysis tool on the **Edinburgh_Wards** feature class, erasing the areas within the **clinic_buffer** feature class from it, and writing the results to a new feature class named "no_service".

15. Run the cell.

16. In the **Contents** pane, uncheck the **all layers, except clinics and no_service.**

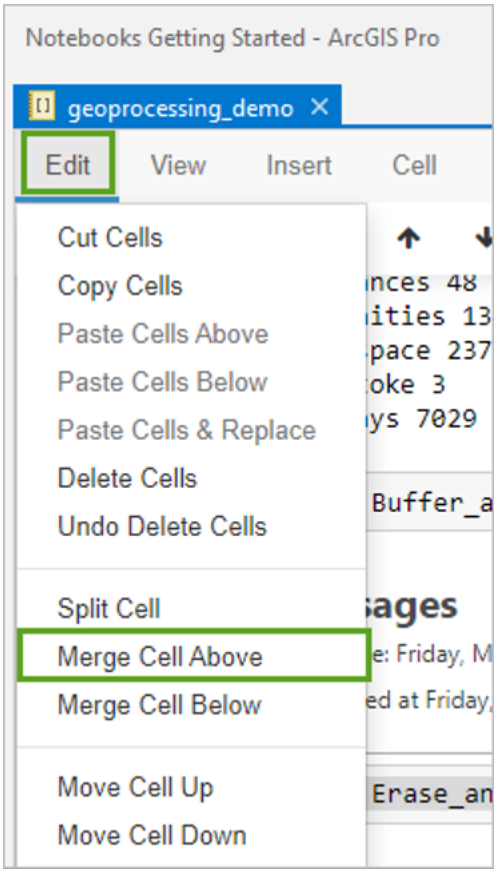
17. Right-click the **no_service** layer and click **Zoom To Layer**.



    The **no_service** layer shows places that are farther from clinics in Edinburgh.

Merging Cells for Workflow Efficiency

18. Click the **arcpy.PairwiseErase_analysis** cell, and in the **Notebook** pane, click the **Edit** menu and click **Merge Cell Above**.



The cells are merged.

```
arcpy.Buffer_analysis("EDI_gis_osm_clinics","buffer","1750 METERS")

arcpy.PairwiseErase_analysis("Edinburgh_Wards", "buffer", "no_service")
```

A benefit of Notebooks, and Python code in general, is that you can quickly run a sequence of tools. In this case, the sequence only consists of two tools, but it illustrates the concept.

19. Change the distance value from 1750 to 2500 and run the cell.

```
arcpy.Buffer_analysis("fire_stations", "fire_buffer", "2500 METERS")

arcpy.PairwiseErase_analysis("etobicoke", "fire_buffer", "no_service")
```

20. Turn off the new **clinic_buffer** layer to see the new **no_service** layer.

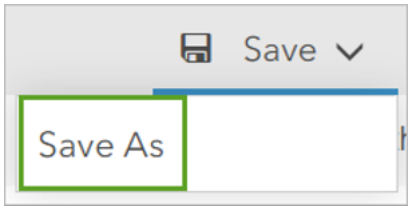
You may need to zoom to the layer to see the remaining smaller areas.

> The resulting areas are potentially the most compromised in terms of clinic service. You were able to obtain this updated result by running the multiple lines of code as a single cell in the notebook. If you had used the tools from their graphical user interfaces, you would have needed to run both the **Buffer** tool and the **Pairwise Erase** tool again to obtain the updated result.
>
> The time savings with only two tools is minor, but many workflows consist of more extended sequences of tools. Additionally, the ability to run a tool or multiple tools within a loop makes Python useful when you need to run the same process on various inputs.

21. Save your ArcGIS Pro project and close.

Create and save a Notebook in ArcGIS Online

1. Go to our ArcGIS Online Organisational account https://uostandrews.maps.arcgis.com/> and log in using your St Andrews email.
2. Click Notebook to open a new ArcGIS Notebook.
3. Click the New Notebook button and you will see a drop-down list with three options: **Standard**, Advanced, and Advanced with GPU support.
4. Click **Standard**.
5. It is a best practice to name and save the notebook when you create it.
6. Click the **Save** button in the upper right of the notebook and then click **Save As.**



When prompted, give the notebook a title, such as My First Notebook followed by an underscore and your first and last initials; some tags, and a summary. Then click Save Notebook. This information will show up on the item page for your notebook in ArcGIS Online.

When you are working in notebooks in ArcGIS Online it is a good idea to save your work regularly.

Work with a notebook

Each new notebook starts with several markdown cells already populated and one code cell that calls the ArcGIS API for Python and connects you to ArcGIS Online. After that, you can add code and markdown cells to create your workflow.

1. Double-click the **Welcome to your notebook** cell to make it editable.

This is a markdown cell. Markdown is a lightweight, plain text formatting syntax that is widely used across the internet. After double-clicking the cell, the text appears in **blue** with two number signs (**##**) in front of it.

Markdown tag welcoming you to your new notebook.

2. While in the markdown cell, click **Run**.

This runs the cell and turn it into a header. You can also run cells by pressing *Shift+Enter* on your keyboard. *Shift+Enter* is the keyboard shortcut for running cells in a notebook.

3. Click Open the command palette at the top of the notebook. This lists of all keyboard shortcuts.

4. Double-click the Welcome to your notebook cell. Insert two more number (**##**) signs in the cell before Welcome to your notebook. There are now four number signs. The additional number signs change the size of the header. Run the cell. The header becomes smaller.

5. Double-click the **Welcome to your notebook** cell again. Remove the two number signs from the header and press **Enter**. On the second line, type **This is my first notebook** and other **other text that you may want to add**. Then, click **Run**.

The header returns to its initial size and there is now text below that cell.

In any new notebook, the second cell will say **Run this cell to connect to your GIS and get started**. This is also a markdown cell. This cell directs you to run the code cell that follows it that connects you to **ArcGIS Online**.

Run this cell to connect to your GIS and get started:

```
In [ ]: from arcgis.gis import GIS
        gis = GIS("home")
```

Run this cell at the beginning of every notebook that connects a user to ArcGIS Online.

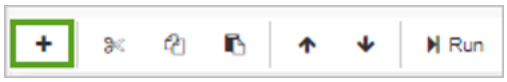
6. Double-click in the code cell and run it.

While the cell runs, an asterisk is inside the brackets in the input area so it appears as In [*]. After the cell finishes running, the number 1 replaces the asterisk in the brackets so it appears as In [1]. The number in the brackets increases by one each time a code cell is run. You must run this cell. If you do not run this cell, the other code cells will not run.

Create a web map.

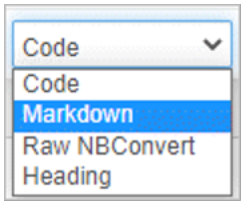
Now that you are familiar with markdown and have run the existing code, you'll write and run some of your own.

1. On the ribbon click the plus (+) sign.



This creates a new cell beneath the code cell that you just ran. The new cell will appear below the currently selected cell.

2. Set that cell to be a markdown cell.



3. In the new markdown cell, type ### **My First Map.**

4. In the same cell, on the second line, add some text below the header that describes the code that you will write. When you are done entering text, **run the cell.**

5. Next, you will create a map in the notebook. Start by creating a new code cell.

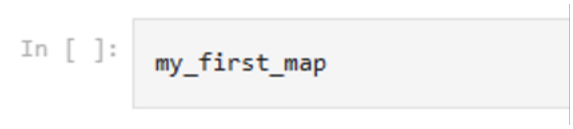
6. In the new code cell, create a variable named **my_first_map** that represents the map and use the ArcGIS API for Python to set the variable to a web map that is centered over a specific location.

7. Set the variable equal to a web map centered on St Andrews, UK:

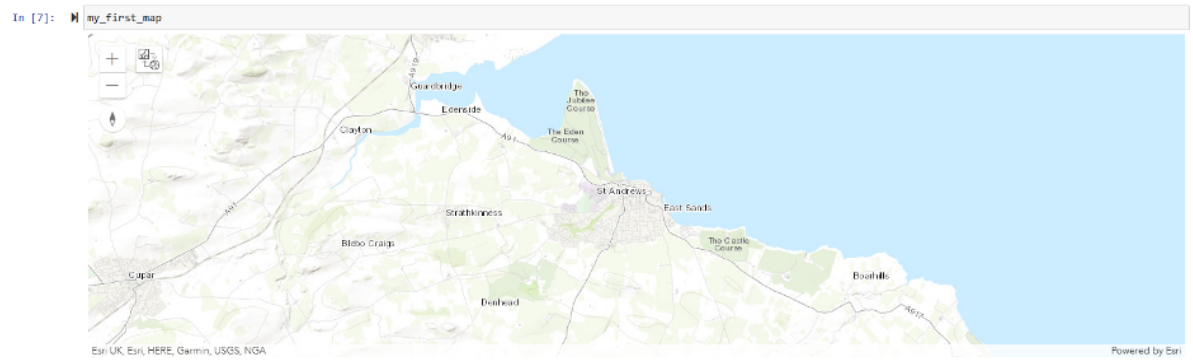
```
my_first_map = gis.map("St Andrews, UK")
```

8. Run the cell.

Now that you have named your variable, you will call it to create the map. Do this by creating a new code cell and then within that code cell, typing **my_first_map** and running that cell.



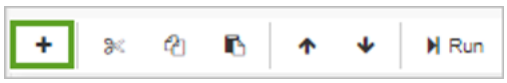
After that cell runs, your first map will appear in your notebook. You can change the location of the center of the map by going back to the previous cell, changing "St Andrews, UK" to a different location, and running the cell again, or you can pan and zoom around the current map.



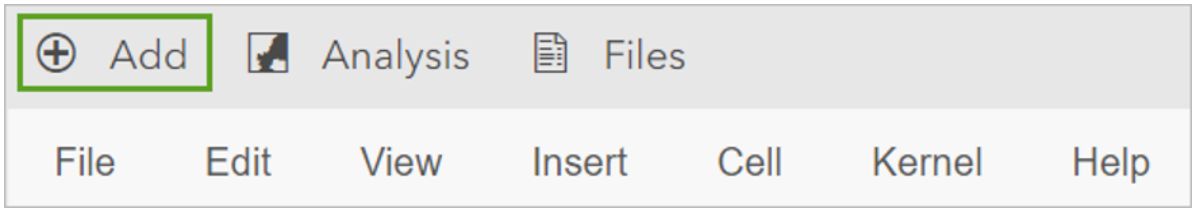
Explore Content

In ArcGIS Notebooks, you can search for content and view item metadata. Next, you will search for a layer over Los Angeles and add it to the notebook.

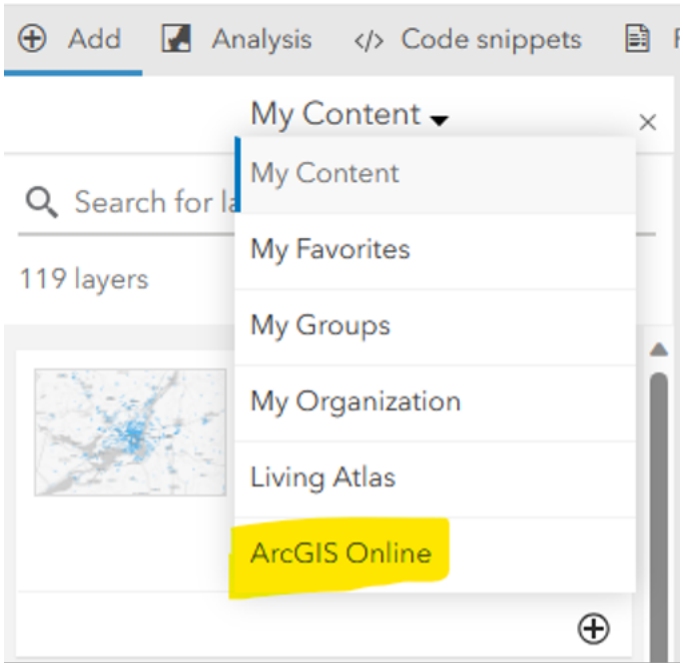
1. On the ribbon click the plus (+) sign. To add a new cell underneath the **my_first_map** cell



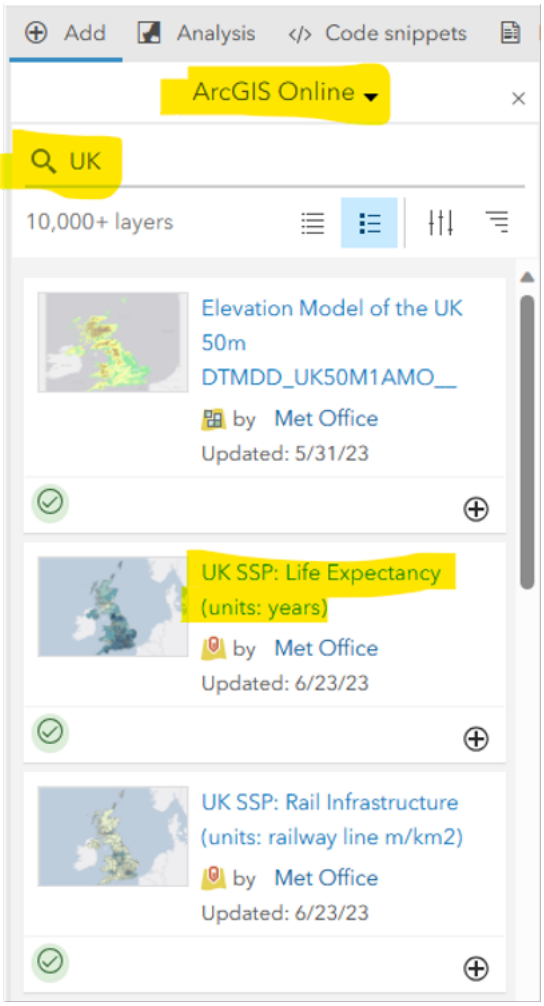
2. Click the **Add** button.



The **Add** button opens the **Add Content** panel, which allows you to add an ArcGIS Online item as code directly to the notebook. If you have saved content in ArcGIS Online or ArcGIS Notebooks, that content is available from the **Add Content** panel to use in your notebook.



3. Click **ArcGIS Online** and type **UK** to search for all content related to the UK and available in ArcGIS Online. Add the UK SSP: Life Expectancy Layer to the notebook by clicking the **add button (a plus sign).**



A new code cell containing a code snippet, is added to the notebook beneath your map. This cell calls the layer as the variable item and loads its metadata. The code cell looks like the following:

```
# Item Added From Toolbar
# Title: UK SSP: Life Expectancy (units: years) | Type: Featu
item = gis.content.get("c7e78a9cad2d4744a13e9c807710b502")
item
```

4. Run this code cell. The item metadata is added as an object to the notebook below the cell, but it is not yet added to the map.

Next, you will learn some short cuts to write code and display relevant documentation.

5. Create a code cell below the item and call your map variable. Type **my__** and press Tab.

Pressing Tab while typing a variable name activates the notebook's autocomplete functionality. The line completes and displays **my_first_map.**

6. After **my_first_map**, type **.ad** so it appears as my_first_map.ad and press Tab.

The code is completed to be **my_first_map.add_layer**

7. **Press Shift+Tab.**

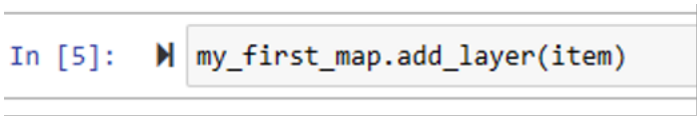
Pressing Shift+Tab opens the docstring. The docstring is a small piece of documentation for developers that describes what the method does.

After investigating the docstring, close it.

You can access the function's help documentation by typing a question mark at the end of the function. For example, **my_first_map.add_layer?** will open the **add_layer** help documentation from the bottom of the notebook. Try this.

After reading the help documentation, close it.

8. In the same cell where you investigated the function signature of my_first_map, call the add_layer method and use it to add the Life expectancy item to the map. **Run the cell**. The cell code should appear as **my_first_map.add_layer(item).**



9. After the cell completes, scroll to the map in your notebook and verify that the new item with the new layer from Met Office has been added.

You have created your first map and added a layer to it using ArcGIS Notebooks. The map includes zoom buttons, a compass, and the option to change from a map view to a globe view.

Pan and zoom the map and use these buttons.

This is a live web map with the same functionality as the maps you use in ArcGIS Online.

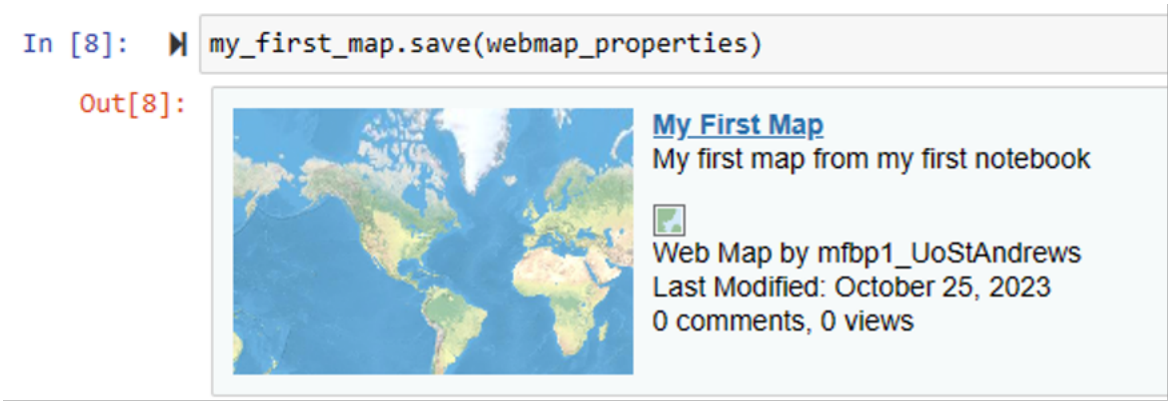
With a few lines of code, you can **save the map** you created to ArcGIS Online. Web maps are defined by specific properties, such as the **title, description (snippet), and tags**. You can define the properties by creating a *dictionary* that contains them in Python code. Then, you can save the map as a web map.

10. In a new code cell, define the web map properties using the following dictionary. You can modify or change the title, snippet, or tags. Run the cell.

```
webmap_properties = {'title':'My First Map', 'snippet': 'My first map from my
first notebook', 'tags':['ArcGIS Notebooks', 'UK']}
```

11. Create another cell where you will save the webmap. Add the following line: **my_first_map.save(webmap_properties)**. Run the cell.

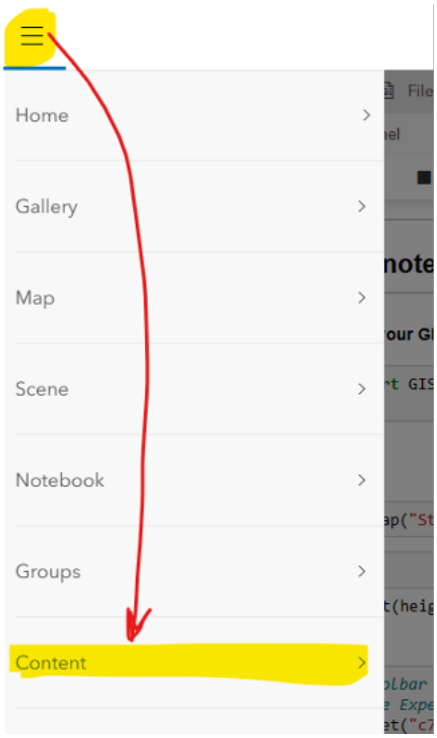
Running this cell creates an active link that will take you to the webmap item in ArcGIS Online. Click the active link and verify that the webmap was created in ArcGIS Online.

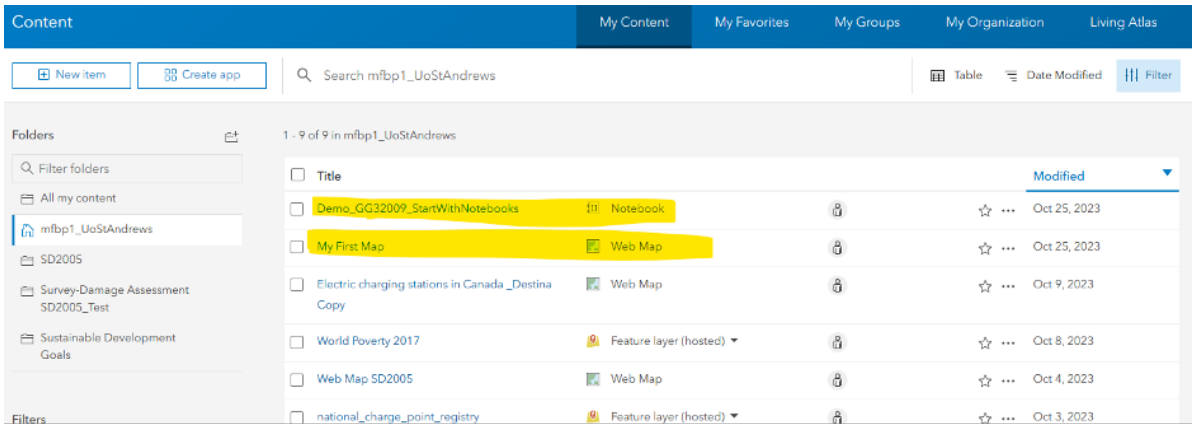


12. Click the **Save** button in the upper right of the notebook.

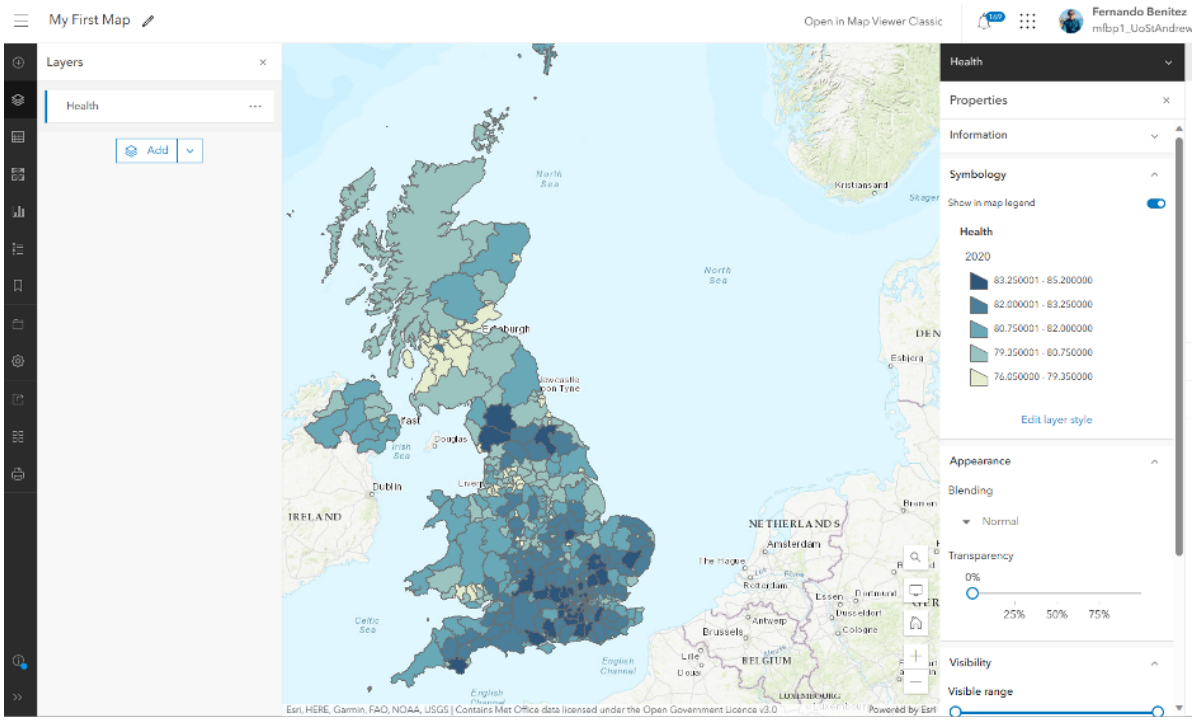
It is a **good idea to save your work regularly** when you work in notebooks hosted online. If there is no Python activity in the notebook for 20 minutes, the Python kernel will shut down, the notebook will stop working, and all variables in memory will be lost. Once you have restarted the kernel you will need to run all of the cells again, starting from the beginning, to restore the values.

13. Go to your **Content**, and check that now you have two new items in your portal. The **notebook**, that you can open and edit it with new code. And the new **WebMap** that you created using Python and the ArcGIS API for Python.





14. Click **My First Map** to open the details, and then click **Open in Map Viewer**. Then ArcGIS Online will launch a viewer to let you explore, edit and share the WebMap you have created.



Challenge for next class

Now that you have learned how to create a map, search for content, add layers, and save a webmap, use **Python and ArcGIS Notebooks** to create another web map that contains multiple layers that you are interested in. Save the webmap to ArcGIS Online.

Be ready to showcase this webmap during the next class showing what the map is about and the difficulties you had

Lab No 2: Python Basics - Part 1

Introduction

Now you have acquired some basic skills of creating new notebooks, run your python environment, the next step and certainty the long process is to learn the python basics of this programming language. This will give you an idea of the 'grammar' that python includes.

Please go to each cell and address the challenges/questions when is required.

Content:

1. How to deal with **variables**.
2. Explain the difference between **Python data types**.
3. Perform mathematical and logical operations.
4. Work with **lists**, **tuples**, **sets**, and **dictionaries**.
5. Apply appropriate **methods** to different data types.

If you need more information or examples, here it is a great resource w3school.com.

Variables

You can think of a **Variable** as anything that related to information or data. A Variable can be a file path on your local machine, could be also a path to a shapefile, could be just a number or letter. Once you create a variable you are assigning a certain space of memory on your computer to storage that information. So you could use it or call it to reference the associated data or object for use in processes and analyses. Note that there are some rules for variable names:

There are certain considerations:

- cannot start with a number or special character (or, can only start with a letter or an underscore) (for example, x1 is valid while 1x is not.).
- can only contain letters, numbers, or underscores. No other special characters are allowed (for example, x, x1, _x, and x1_ are all valid. x$ is not valid.).

- are case-sensitive (for example, x1 and X1 are two separate variables).

Since Python is an object-based language, you will primarily interact with your data using variables. The *print()* function is used to print the data referenced by the variable.

```
x = 1
y = "Python"
x1 = 2
y1 = "Spatial Data"
_x = 3
_y = "Web GIS"
print(x)
print(y)
print(x1)
print(y1)
print(_x)
print(_y)
```

You can also assign data to multiple variables as a single line of code as demonstrated below. In Python variable names are dynamic, so you can overwrite them. This can, however, be problematic if you overwrite a variable name accidentally. So, use unique names if you do not want to overwrite prior variable.

```
x, x1, _x = 1, 2, 3
print(x)
print(x1)
print(_x)
```

Assignment Operators are used to assign values or data to variables. The most commonly used operator is =. However, there are some other options that allow variables to be manipulated mathematically with the resulting value saved back to the original data object that the variable references. These additional assignment operators can be useful, but you will use the = operator most of the time.

For example, += will add a value to the current value and assign the result back to the original variable. In the first example below, x references the value 2. The += assignment operator is then used to add 3 to x and save the result back to x. Work through the provided examples and make sure you understand the use of each operator.

```
x = 2
print(x)
x += 3
```

```
print(x)

x = 2
print(x)
x -= 3
print(x)

x = 2
print(x)
x *= 3
print(x)

x = 2
print(x)
x /= 3
print(x)

x = 2
print(x)
x **= 3
print(x)
```

Important Note:

In the cell bellow, you will run small experiment that explains some important behavior of Python. You have defined a variable a that holds a **list** of three values. We will discuss **lists** later in this section. Now, you create a new variable b and assign it to be equal to a. Layer you edit the variable a by appending a new value to the list (You will see how this is done later, so don't worry if you don't understand how this works yet). When you print a and b, you can see that both variables contain the same set of numbers in the list even though you added 8 to a after setting b equal to a. Or, the change that you made to a was also applied to b.

In Python, certain types of objects, such as lists, are **mutable**. This means that it is possible to change the data stored in memory and referenced to the variable. When a mutable object is altered, all variables that point to it will reflect this change. What this means practically is that setting b equal to a results in a and b pointing to the same object or data in memory. So, changes to a or b will be reflected in both variables since the data being referenced by both have been updated.

If you have experience in **R**, and I guess you do, you will see how Python is different, as in R, setting a variable equal to another variable would make a copy that was not linked and could

be altered without changing the original variable.

To test whether two variables reference the same object in memory, you can use the *is* keyword. if *True* is returned, then they reference the same object. You can also print the object ID, which represents the memory address for the object, using the *id()* function. Using both methods below, you can see that *a* and *b* reference the same object.

```
a = [5, 6, 7]
b = a
a.append(8)
print(a)
print(b)

print(a is b)
print(id(a))
print(id(b))
```

What if you wanted to make a copy of a variable referencing mutable data that does not reference the same object?

For example, you may want to be able to make changes to *a* that do not impact *b*. This can be accomplished using the *copy()* or *deepcopy()* functions from the **copy** module.

Check how now we import a new package, module or library to get new functionalities.

In the experiment below, You have defined *b* as a deep copy of *a*. Now, changes made to *a* do not impact *b*. This is because they do not reference the same object in memory since *deepcopy()* makes a copy of the object or data to a new location in memory. This is confirmed using *is* and *id()*.

```
import copy
a = [5, 6, 7]
b = copy.deepcopy(a)
a.append(8)
print(a)
print(b)

print(a is b)
print(id(a))
print(id(b))
```

Comments (Important for clear and scalable coding)

Now please pay attention as this is the key of many developers and analysts, you need to learn how to commenting your code. **Comments** are used to make your code more readable and are not interpreted by the computer. Instead, they are skipped and meant for humans. Different languages use different syntax to denote comments. Python uses the hashtag or pound sign. You can add comments as new lines or following code on the same line.

Unfortunately, Python does not have specific syntax for multi-line comments. However, this can be accomplished by adding hashtags before each separate line or using a multi-line string that is not assigned to a variable. Examples are shown below.

It is generally a good idea to comment your code for later use and for use by others. In fact you need to comment your code for all assignments and exercises you run in this part of the course.

```
#Single-line comment
x = 1
y = 2 #Another single-line comment
#A
#multi-line
#comment
z = 3
"""
Another multi-line comment
"""
w = 4
```

Data Types

A variety of **data types** are available in Python to store and work with a variety of input. Below are explanations of the data types which you will use most often. There are additional types that we will not discuss.

When creating a variable, it is not generally necessary to explicitly define the data type. However, this can be accomplished using **constructor functions** if so desired. Constructor functions can also be used to change the data type of a variable, a process known as **casting**.

Available constructor methods include *str()*, *int()*, *float()*, *complex()*, *list()*, *tuple()*, *dict()*, *set()*, and *bool()*.

To determine the data type, you can use the *type()* function. See the examples below where I convert an integer to a float and then a float to a string.

- **Numeric**
  - **Int** = whole numbers
  - **Float** = numbers with decimal values
  - **Complex** = can include imaginary numbers
- **Text**
  - **String** = characters or numbers treated as characters
- **Boolean**
  - **Boolean** = logical *True* or *False*
- **Sequence**
  - **List** = list of features that can be re-ordered, allows for duplicates, and is indexed
  - **Tuple** = list of features that cannot be re-ordered, allows for duplicates, and is indexed
- **Mapping**
  - **Dictionary** = list of features that can be re-ordered, does not allow duplicates, is indexed, and contains **key** and **value** pairs
- **Set**
  - **Set** = list of features that are unordered, not indexed, and does not allow for duplicates

```
#Create a variable and check the data type
x = 1
print(type(x))
#Change the data type
x = float(x)
print(type(x))
x= str(x)
print(type(x))
```

Numbers

Regardless of the the type (integer, float, or complex), numbers are defined without using quotes. If a number is placed in quotes it will be treated as a string as demonstrated below. This is important, since the behavior of the data is altered. In the example, x represents 1 as a number while y represents "1" as a string (note the quotes). Adding x to itself will yield 2 (1 + 1). Adding y to itself will yield "11", or the two strings are combined or **concatenated**.

```
#Create variables
x = 1
y = "1"
print(x + x)
print(y + y)
```

Numbers support mathematical operations, as demonstrated below. If you are not familiar with these concepts, **modulus** will return the remainder after division while **floor division** will round down to the nearest whole number after division.

If a whole number has no decimal values included or no period (1 vs. 1. or 1.0), this implies that the output is in the integer data type as opposed to float type.

```
x = 4
y = 3
print(x + y) #Addition
print(x - y) #Subtraction
print(x * y) #Multiplication
print(x / y) #Division
print(x % y) #Modulus
print(x ** y) #Exponentiation
print(x // y) #Floor Division
```

Strings

Strings are defined using single or double quotes. If quotes are included as part of the text or string, then you can use the other type to define the data as text. Again, numbers placed in quotes will be treated as strings.

```
x = "Python"
y = "is great" #Must use double quotes since a single quote is use in the string
z = "2" #Number treated as a string
print (x,y,z)
```

Portions of a string can be sliced out using **indexes**.

Very important note: In Python the indexing starts at 0 as opposed to 1., like in **R** So, the first character is at index 0 as opposed to index 1. Negative indexes can be used to index relative to the end of the string. In this case, the last character has an index of -1.

Indexes combined with square brackets can be used to slice strings. Note that the last index specified in the selection or range will not be included and that spaces are counted in the indexing.

```
x = "GG3209 Spatial Analysis with GIS"
print(x[0:6])
print(x[7:14])
print(x[15:23])
print(x[-3:])
```

Strings can be combined or **concatenated** using the addition sign. If you want to include a number in the string output, you can **cast** it to a string using *str()*. In the example below, note the use of blank spaces so that the strings are not ran together.

The *len()* function can be used to return the length of the string, which will count blank spaces along with characters.

```
x = "Spatial"
xx="GG"
y = 3209
z = "Analysis"
w = "With Python"
strng1 = xx + str(y) + " "+ x + " " + z + " " + w
print(strng1)
print(len(strng1))
```

Method

A **method** is a function that belongs to or is associated with an object. Or, it allows you to work with or manipulate the object and its associated properties in some way. Data types have default methods that can be applied to them.

Methods applicable to strings are demonstrated below. Specifically, methods are being used to change the case and split the string at each space to save each component to a list.

```
x = "GG3209 Spatial Analysis with GIS"
print(x.upper())
print(x.lower())
lst1 = x.split(" ")
print(lst1)
```

When generating strings, issues arise when you use characters that have special uses or meaning in Python. These issues can be alleviated by including an **escape character** or backslash as demonstrated below.

```
s1 = "Issue with \"quotes\" in the string."
s2 = "C:\\data\\project_1" #Issue with file paths.
s3 = "Add a new line \nto text string"
print(s1)
print(s2)
print(s3)
```

Booleans

Booleans can only be *True* or *False* and are often returned when an expression is logically evaluated.

A variety of **comparison operators** are available. Note the use of double equals; a single equals cannot be used since it is already used for variable assignment, or is an assignment operator, and would thus be ambiguous.

- **Comparison Operators**
  - **Equal**: ==
  - **Not Equal**: !=
  - **Greater Than**: >
  - **Greater Than or Equal To**: >=
  - **Less Than**: <
  - **Less Than or Equal To**: <=

Logical statements or multiple expressions can be combined using **Logical Operators**.

- **Logical Operators**:
  - A AND B: **and**
  - A OR B: **or**
  - A NOT B: **not**

```
x = 3
y = 7
z = 2
print(x == 7)
print(x > y)
print(x < y)

print(x < y and x > z)
print(x < y and x < z)
print(x < y or x < z)
```

You can also assign Booleans to a variable. Note that you do not use quotes, as that would cause the text to be treated as a string instead of a Boolean.

```
x = "True"
y = True
print(type(x))
print(type(y))
```

Lists

Now one of the very relevant type of objects in Python. **Lists** allow you to store multiple numbers, strings, or Booleans in a single variable. Square brackets are used to denote lists.

Items in a **list** are ordered, indexed, and allow for duplicate members. Indexing starts at 0. If counting from the end, you start at -1 and subtract as you move left. A colon can be used to denote a range of indexes, and an empty argument before the colon indicates to select all elements up to the element following the colon while an empty argument after the colon indicates to select the element at the index specified before the colon and all features up to the end of the list. The element at the last index is not included in the selection.

Python lists can contain elements of different data types.

```
lst1 = [6, 7, 8, 9, 11, 2, 0]
lst2 = ["A", "B", "C", "D", "E"]
lst3 = [True, False, True, True, True, False]
print(lst1[0])
print(lst1[0:3])
print(lst2[-4:-1])
print(lst2[:3])
print(lst2[3:])
lst4 = [1, 2, "A", "B", True]
print(type(lst4[0]))
print(type(lst4[2]))
print(type(lst4[4]))
```

When the *len()* function is applied to a list, it will return the number of items or elements in the list as opposed to the number of characters. When applied to a string item in a list, this function will return the length of the string.

```
lst1 = ["A", "B", "C", "D", "E"]
print(len(lst1))
print(len(lst1[0]))
```

The code below shows some example methods for strings.

```
lst1 = ["A", "B", "C", "D", "E"]
lst1.append("F") #Add item to list
print(lst1)
lst1.remove("F") #Remove item from a list
print(lst1)
lst1.insert(2, "ADD") #Add item to list at defined position
print(lst1)
lst1.pop(2) #Remove item at specified index or the last item if no index is provided
print(lst1)
```

As explained above, in order to copy a list and not just reference the original data object, you must use the *copy()* or *deepcopy()* method. Simply setting a new variable equal to the original list will cause it to reference the original data object, so changes made to the old list will update to the new list. This is demonstrated in the example below.

```
lst1 = ["A", "B", "C", "D", "E"]
lst2 = lst1
lst3 = lst1.copy()
print(lst2)
print(lst3)
lst1.append("F")
print(lst2)
print(lst3)
```

Lists can be concatenated together, or a list can be appended to another list, using the methods demonstrated below.

```
lst1 = ["A", "B", "C"]
lst2 = ["D", "E", "F"]
lst3 = lst1 + lst2
print(lst1)
print(lst2)
print(lst3)
lst1.extend(lst2)
print(lst1)
```

Lastly, lists can contain other lists, tuples, or dictionaries, which will be discussed below. In the example, *lst2* contains four elements, the last of which is a list with three elements.

```
lst1 = ["A", "B", "C"]
lst2 = ["D", "E", "F", lst1]
print(lst2)
```

Tuples

Tuples are similar to lists in that they are ordered and allow duplicate elements. However, they cannot be altered by adding items, removing items, or changing the order of items. To differentiate them from lists, parenthesis are used as opposed to square brackets. Think of tuples as lists that are protected from alteration, so you could use them when you want to make sure you don't accidentally make changes.

If you need to change a tuple, it can be converted to a list, manipulated, then converted back to a tuple.

```
t1 = (1, 3, 4, 7)
print(type(t1))
```

Dictionaries (not the one for spelling)

Dictionaries are unordered, changeable, indexed, and do not allow for duplicate elements. In contrast to lists, tuples, each **value** is also assigned a **key**.

And here is the key –> Values can be selected using the **associated key**.

You can also use the key to define a value to change.

Similar to lists, you must use the *copy()* or *deepcopy()* method to obtain a copy of the dictionary that will not reference the original data or memory object.

```
cls = {"code": "GG3209", "Name":"Spatial Analysis with Python" }
print(cls)
print(cls["Name"])
cls["Code"] = 461
print(cls)
```

Multiple dictionaries can be combined into a **nested dictionary**, as demonstrated below.

The keys can then be used to extract a sub-dictionary or an individual element from a sub-dictionary.

```
cls1 = {"prefix" : "GG", "Number" : 3209, "Name": "Spatial Analysis with Python"}
cls2 = {"prefix" : "GG", "Number" : 3210, "Name": "Advanced Analysis with Python"}
cls3 = {"prefix" : "GG", "Number" : 3211, "Name": "Introduction to Remote Sensing"}
cls4 = {"prefix" : "GG", "Number" : 3212, "Name": "Web GIS"}
clsT = {
    "class1" : cls1,
    "class2" : cls2,
    "class3" : cls3,
    "class4" : cls4
}
print(clsT)
print(clsT["class1"])
print(clsT["class1"]["Name"])
```

Additional Types

Arrays

Arrays are similar to lists; however, they must be declared.

They are sometimes used in place of lists as they can be very compact and easy to apply mathematical operations. However in this course, we will primarily work with **NumPy** arrays, which will be discussed in more detail in a later module.

If you wanna know how an array looks like, here is an example

```
my_array = [1, 2, 3, 4, 5]
print(my_array[0])   # Output: 1
print(my_array[2])   # Output: 3
```

You can also modify elements in the array by assigning a new value to a specific index:

```
my_array[1] = 7
print(my_array)      # Output: [1, 7, 3, 4, 5]
```

Classes

Now some a more complex type of object in Python: **Classes** are used to define specific types of objects in Python and are often described as templates.

Once a class is defined, it can be copied and manipulated to create a **subclass**, which will inherit properties and methods from the parent class but can be altered for specific uses. You get more details in the next Notebook (Part 2). You will also see example uses of classes in futher examples.

One use of classes is to define specialized data models and their associated methods and properties. For example, classes have been defined to work with geospatial data types.

```
class Dog:
    def __init__(self, name, breed):
        self.name = name
        self.breed = breed

    def bark(self):
        print("Woof!")

my_dog = Dog("Buddy", "Golden Retriever")
print(my_dog.name)    # Output: Buddy
print(my_dog.breed)   # Output: Golden Retriever
my_dog.bark()         # Output: Woof!
```

In the example above, we've defined a class called **Dog** that has a constructor method "**init** that takes two **parameters**, *name* and *breed*.

Inside the constructor, we assign the passed-in values to *instance* (re-create the object) variables with the same names using the *self* keyword.

We've also defined a method called bark that simply prints out "Woof!" when called. To call this method on *an instance* of the Dog class, we first create an instance of the class by calling the constructor and passing in the required parameters, and then we call the bark method on that instance.

Final remarks

Before moving on, I wanted to note which data types are **mutable** and which are **immutable**.

Again, data or objects that are mutable can be altered after they are defined (such as adding a new element to a list).

Mutable types include **lists**, **sets**, and **dictionaries**.

Immutable types include **booleans**, **integers**, **float**, **complex**, **strings**, and **tuples**.

Next Step

Once you finish this, now clone **Python_Basics_Part2**, In that notebook, we will discuss more components of Python including functions, control flow, loops, modules, and reading data from disk.

References

1. PythonGIS
2. Python Data Spatial

Lab No 3: Python Basics - Part 2

Introduction

We will now discuss additional components of the Python language including **functions**, **flow control**, **loops**, **modules**, and **reading/writing** data from disk. It is important you learn effective ways to make your code efficient, as python can be memory-consuming, but at the same time learn how to create Loops, and flow control will help to run tasks in an automatic ways making your scripts a powerful tool.

If you have some experience with this type of conditions or components from your previous courses with R, you will see that the logic is the same. Reading and writing files using python is also a key skill to learn, as in most of the cases you will need to access files, or folders where your spatial data is located.

Please go through every cell, reading carefully all descriptions and run the code cell to see the examples, you later might want to use this notebook to recall how to create the following components:

Content

1. Define and use **functions**.
2. Use **If...Else** statements, **While Loops**, and **For Loops**.
3. Describe and interpret **classes** and **methods**.
4. Access and use **modules** and **libraries**.
5. Work with local files and directories.
6. Use **f-strings** and **list comprehension**.

If you need more information or examples Here it is a great resource w3school.com.

2. Functions

Functions are probably one of the key components in any programming language, **Functions** do something when called. You can think of those as tools. **Methods**, which we will discuss

in more detail later in this notebook, are like functions except that they are tied to a specific **object**.

When creating a new **class**, you can define methods specific to the new class. Functions generally have the following generic syntax:

```
output = function(Parameter1, Parameter2). #Think of parameters as Inputs., so you have outpu
```

In contrast, methods will have the following generic syntax:

```
output = object.method(Parameter1, Parameter2).
```

Below, You are generating a simple function that multiplies two numbers together.

The *def* keyword is used when defining a function. Within the parenthesis, a list of **parameters**, which are often specific inputs or required settings, can be provided.

```
In the below example, the function accepts two parameters: *a* and *b*. On the next line, inc
```

Once a function is created, it can be used. In **Example 1**, You will see two **arguments**, or values assigned to the parameters, and save the result to a variable *x*.

Then when using a function, it is also possible to provide the arguments as *key* and *value* pairs, as in **Example 2**.

When creating a function, default arguments can be provided for parameters when the function is defined. If arguments are not provided when the function is used, then the default values will be used, as demonstrated in **Example 3**.

2.1 Indentation

This is a good time to stop and describe indentation.

Python makes use of **whitespace**, indentations, or tabs to denote or interpret units of code. This is uncommon, as most other languages use brackets or punctuation of some kind. So, it is important to properly use indentations or your code will fail to execute correctly or at all.

```
#Example 1
def multab(a,b):
    return a*b

x = multab(3,6)
print(x)

#Example 2
x = multab(a=5, b=3)
print(x)

#Example 3
def multab(a=1,b=1):
    return a*b
x = multab()
print(x)
```

Challenge 2.1

In the next code cell, create a function that transform the distance in miles to kilometers between London and Edinburgh. **Try no to google or use ChatGPT for this challenge, as those will provide more advance suggestion, you will only need the previous cell description to run this challenge.**

2.2 Options *args and **kwargs for functions

There are a few other options when defining functions that increase flexibility. For example, what if you wanted to edit the function created above so that it can accept more than two arguments and so that the number of arguments can vary? This can be accomplished using either ***args** or ****kwargs**.

***args**:

A single asterisk (*) is used to unpack an iterable, such as a list, whereas two asterisks (**) are used to unpack a dictionary. Using *args allows you to to provide a variable number of non-keyword arguments (or, each argument does not need to be assigned a key). In contrast, **kwargs is used to provide a variable number of keyword arguments (or, each argument must have a key).

In the **first example** below, You altered the function from above to accept two or more arguments.

Within the function, later you define a variable *x1* that initially assigned a value of 1. Then, inside of a **for loop**, which will be discussed later, you iteratively multiply *x1* by the next provided value. To test the function, a feed it the values 1 through 5 as non-keyword arguments.

The result is calculated as 1x1 –> 1x2 –> 2x3 –> 6x4 –> 24x5 –> 120.

Note that the single asterisk is key here. The work "args" could be replaced with another term, as the second part of the example demonstrates. What is important is that * is used to unpack an iterable.

```
# Example 1

def multab(*args):
    x1 = 1
    for a in args:
        x1 *= a
    return x1

x = multab(1, 2, 3, 4, 5)
print(x)

#Example 2

def multab(*nums):
    x1 = 1
    for a in nums:
        x1 *= a
    return x1

x = multab(1, 2, 3, 4, 5)
print(x)
```

****kwargs**:

The next example demonstrates the use of **kwargs. Here, the arguments must have keys. Again, what is important here is the use of ** to unpack a dictionary: "kwargs" can be replaced with another term. Note the use of the *.values()* method for a dictionary. This allows access to the values as opposed to the associated keys.

```
def multab(**kwargs):
    x1 = 1
    for a in kwargs.values():
        x1 *= a
    return x1

x = multab(a=1, b=2, c=3, d=4, e=5)
print(x)

def multab(**nums):
    x1 = 1
    for a in nums.values():
        x1 *= a
    return x1

x = multab(a=1, b=2, c=3, d=4, e=5)
print(x)
```

The next cell demonstrates the use of the single asterisk to unpack an iterable, in this case a list. Each element in the list is returned separately as opposed to as a single list object. This is the same functionality implemented by *args.

```
x = [2,3,4,5]
print(*x)
```

Lastly, it is possible to use both ***args** and ****kwargs** in the same function.#

However, ***args** must be provided before ****kwargs**. In the example below, the parameter a is provided an argument of 1 while the parameter b is provided an argument of 2. 3 would be associated with *args, since it is not assigned a key, while 4 and 5 would be associated with **kwargs since they are assigned a key.

```
# Create a function
def multab(a=2, b=2, *args, **kwargs):
    x1 = 1 #Define variables
    x1 *= a
    x1 *= b
    if args: # Conditional
        for arg in args: #Loop
            x1 *= arg
    if kwargs:
        for kwarg in kwargs.values():
```

```
            x1 *= kwarg
    return x1

x = multab(1, 2, 3, c=3, d=4)
print(x)
# Read description below to understand how this function works, looks more complicated than a
```

As the examples above demonstrate, *args and **kwargs increase the flexibility of functions in Python by allowing for variable numbers of arguments. Even if you do not make use of these options, they are important to understand, as many functions that you encounter will make use of them. So, knowledge of this functionality will aid you in understanding how to implement specific functions and interpret the associated documentation.

NOTE:

The following options will you give an additional level of skill in Python. Although they are rarely included in python basics, we consider that if you can master those, you will have an extra level of expertise and will definitely help you to make more efficient programs using python.

2.3 Lambda

A **lambda function** is a special function case that is generally used for simple functions that can be anonymous or not named. They can accepted multiple arguments but can only include one expression. Lambda functions are commonly used inside of other functions.

```
lam1 = lambda a, b, c: str(a) + " " + str(b) + " " + str(c)
print(lam1("Geospatial", "Data", "Science"))

a = "Geospatial"
b = "Dasta"
c = "Science"
```

2. Scope

Variables are said to have **global scope** if they can be accessed anywhere in the code.

In contrast, **local scope** implies that variables are only accessible in portions of the code.

For example, by default new variables defined within a function cannot be called or used outside of the function. If you need to specify a variable within a function as having global scope, the *global* keyword can be used.

In the first example below, the variables xG, yG, and z have global scope, so can be called and used outside of the function. In contrast, variables xL and yL have local scope and are not available outside of the function. If you attempt to run the last line of code, which is commented out, you will get an error.

```
xG = 2
yG = 3
def Func1(a, b):
    xL = a*a
    yL = b*b
    return xL + yL

z = Func1(xG, yG)
print(xG)
print(z)
#print(xL+3) will not work due to local scope
```

If you need a variable declared inside of a function to have global scope, you can use the *global* keyword as demonstrated below.

```
xG = 2
yG = 3
def Func1(a, b):
    global xL
    xL = a*a
    global yL
    yL = b*b
    return xL + yL

z = Func1(xG, yG)
print(xG)
print(z)
print(xL+3)
```

3. Pass

It is not possible to leave a function empty when it is defined. As you develop code, you can make use of the *pass* keyword as a placeholder before adding content to a function. This will

allow you to work with your code without errors until you complete the content within the function. *pass* can also be used within incomplete class definitions and loops.

```
def multab(x, y):
    pass
```

Conditionals - Control Flow

1. If...Else

All coding languages allow for **control flow** in which different code is executed depending on a condition.

If...Else statements are a key component of how this is implemented. Using logical conditions that evaluate to **True** or *False*, it is possible to program different outcomes. Think about this as the rules, if something is **True**, then **do this**, but if something is **False**, then **do that**.

The first example uses only **if**. So, if the condition evaluates to **True**, the remaining code will be executed. If it evaluates to **False** then nothing is executed or returned. In this case, the condition evaluates to **True**, so the text is printed.

Again, remember that indentation is very important in Python. The content of the *if* statement must be indented or the code will fail.

```
x = 7
if x > 6:
    print(str(x) + " is greater than 6.")
```

It is common to have a default statement that is executed if the condition evaluates to *False* as opposed to simply doing nothing. This is the use of an *else* statement. No condition is required for the *else* statement since it will be executed for any case where the *if* condition evaluates to *False*. Again, note the required indentation.

```
x = 3
if x > 6:
    print(str(x) + " is greater than 6.")
else:
    print(str(x) + " is less than or equal to 6.")
```

What if you want to evaluate against more than one condition? This can be accomplished by incorporating one or multiple *elif* statements. The code associated with the *else* statement will only be executed if the *if* and all *elif* statements evaluate to *False*.

All statements should be mutually exclusive or non-overlapping so that the logic is clear. In the second example, I have changed the first condition to $x >= 6$, so now the condition in the *if* and *elif* statements overlap. When the code is executed, the result from the *if* statement is returned. Since the first condition evaluated to *True*, the associated code was executed and the *elif* and *else* statements were ignored. If I swap the *if* and *elif* conditions, a different result is obtained. So, the order matters. In short, this ambiguity can be avoided by using conditions that are mutually exclusive and non-overlapping.

```
x = 6
if x > 6:
    print(str(x) + " is greater than 6.")
elif x == 6:
     print(str(x) + " is equal to 6.")
else:
    print(str(x) + " is less than 6.")
```

```
x = 6
if x >= 6:
    print(str(x) + " is greater than 6.")
elif x == 6:
     print(str(x) + " is equal to 6.")
else:
    print(str(x) + " is less than 6.")


x = 6
if x == 6:
     print(str(x) + " is equal to 6.")
elif x >= 6:
     print(str(x) + " is greater than 6.")
else:
    print(str(x) + " is less than 6.")
```

2. While Loop

While loops are used to loop code as long as a condition evaluates to *True*. In the example below, a variable i is initially set to 14.

The loop executes as long as i remains larger than 7. At the end of each loop the -= **assignment operator** is used to subtract 1 from i. Also, i is simply a variable, so you do not need to use i specifically. For example, i could be replaced with x.

Please consider the following, **One potential issue with a while loop** is the possibility of an **infinite loop** in which the loop never stops because the condition never evaluates to *False*. For example, if I change the assignment operator to *+=*, the condition will continue to evaluate to *True* indefinitely.

```
i = 14
while i > 7:
    print(i)
    i -= 1
```

3. For Loop

For Loops will execute code for all items in a sequence. For loops make use of data types that are **iterable**, or that can return each individual element in the data object sequentially (for example, each string element in a list). Data types that are iterable include **lists**, **tuples**, **strings**, **dictionaries**, and **sets**.

In the first example below, a for loop is being used to print every value in a list. In the next example, each character in a string is printed sequentially. Both lists and strings are iterable, so can be looped over.

```
lst1 = [3, 6, 8, 9, 11, 13]
for i in lst1:
    print("Value is: " + str(i))
```

```
str1 = "Remote Sensing"
for c in str1:
    print(c)
```

Combining a for loop and If…Else statements allows for different code to be executed for each element in a sequence or iterable, such as a list, based on conditions, as demonstrated in the code below. In later modules, you will see example use cases for working with and analyzing spatial data. Note the levels of indentation used, which, again, are very important and required when coding in Python. The content in the for loop is indented with one tab while the content within the *if*, *elif*, and *else* statements, which are include in the for loop, are indented with two tabs.

```
lst1 = [3, 6, 8, 9, 11, 13]
for i in lst1:
    if i < 8:
        print(str(i) + " is less than 8.")
```

```
    elif i == 8:
        print(str(i) + " is equal to 8.")
    else:
        print(str(i) + " is greater than 8.")
```

The *range()* function is commonly used in combination with for loops. Specifically, it is used to define an index for each element in an iterable that can then be used within the loop.

In the example below, *range()* is used to define indices for all elements in a list. The *len()* function returns the length, so the returned indices will be 0 through the length of the list, in this case 4. The for loop will iterate over indices 0 through 3 (the last index is not included). This allows for the index to be used within the loop. In the example, the index is used to extract each element from the list and save it to a new local variable (*country*), which is then provided to a print statement.

```
countries = ["Belgium", "Mexico", "Italy", "India"]
for i in range(len(countries)):
    country = countries[i]
    print("I would like to visit " + country + ".")
```

Another function that is commonly used in combination with for loops is *enumerate()*. For each element in the iterable, *enumerate()* will return an index and the element. Both can then be used within the loop.

In the first example below, *enumerate()* is used to create an index and extract each element in the list sequentially. In this case, the enumeration is not necessary, since the index is not needed. However, in the next example, the index is used to print different results depending on whether the index is even or odd. So, *enumerate()* is needed because I need access to both the index and the data element within the loop.

```
countries = ["Belgium", "Mexico", "Italy", "India"]
for index, country in enumerate(countries):
    print("I would like to visit " + country + ".")
```

```
countries = ["Belgium", "Mexico", "Italy", "India"]
for index, country in enumerate(countries):
    if index%2 == 0:
        print("I would like to visit " + country + ".")
    else:
        print("I would not like to visit " + country + ".")
```

There are some other useful techniques for flow control, code development, and error handling that we will not discuss in detail here. For example, **try**, **except**, and **finally** can be used to to handle errors and provide error messages. **break** is used to terminate a for loop based on a condition. **continue** can be used to skip the remaining steps in an iteration and move on to the next iteration in a loop.

List Comprehension - Great Feature from Python!

List comprehension is a nice feature in Python.

This technique allows you to create a new list from elements in an existing list and offers more concise syntax than accomplishing the same task using a for loop.

In the first example, You will see that we use a list comprehension to return each element (*c*) in *lst1* to a new lst, *lst2*, if the string starts with the letter "B". Here is how you would read the syntax within the square brackets:

- "Return the element (*c*) from the list (*lst1*) if its first character is"B".

In the second example, no condition is used. Instead, you are concatenating "I would like to visit" to each country and returning each result as an element in a new list.

You will see examples of list comprehension in later modules. It is a very handy technique.

```
# Example 1

lst1 = ["Belgium", "Mexico", "Italy", "India", "Bulgaria", "Belarus"]
lst2 = [c for c in lst1 if c[0] == "B"]
print(lst2)
```

```
# Example 2

lst1 = ["Belgium", "Mexico", "Italy", "India", "Bulgaria", "Belarus"]
lst2 = ["I would like to visit " + c for c in lst1]
print(lst2)
```

Classes

We briefly covered **classes** in the previous notebook. Here, we will provide a more in-depth discussion.

Since Python is an object-based language, it is important to be able to define different types of objects. Classes serve as blueprints for creating new types of objects. Thus, the concept, use, and application of classes is very important in Python.

To create a new class, you must use the *class* keyword. In the following example, you are generating a new class called *Course*. To construct a class, you must use the *___init___()* function. Within this function, you can assign values to object properties, and *___init___()* will be executed any time a new instance of the class is created. When You create an instance of my *Course* class, three properties will be initiated: **the subject code**, **course number**, and **course name*.

self references the current instance of the class. Although you can use a term other than *self*, *self* is the standard term used. Regardless of the term used, it must be the first parameter in *___init___()*.

After the *___init___()* function, you then define a **method** that will be associated with the class. This method, **printCourse()**, will print the course name. Again, methods are functions that are associated with an object or class.

In order to use the method, You must first create an instance of the class and provide arguments for the required parameters. You can then apply the method to the instance to print the course info.

Once an instance of a class is created, the arguments assigned to properties can be changed using the following generic syntax: instance.property = new argument. Here you are changing the *number* parameter of the *x* instance of the *Course* class to 350. and then use my *printCourse()* method again.

```
class Course:
    def __init__(self, subject, number, name):
        self.subject = subject
        self.number = number
        self.name = name
    def printCourse(self):
        print("Course is " + self.subject + ": " + self.name + " with the code: " + str(self

x = Course("Spatial Analysys", 33209, "Using Python")
x.printCourse()
type(x)

x.number = 350
x.printCourse()
```

Once a class is created, **subclassess** can be derived from it. By default, subclasses will take on the properties and methods of the parent or superclass. However, you can alter or add

properties and methods. This allows you to start with a more generic blueprint and refine it for a specific use case, as opposed to building a new class from scratch.

In the example below, I have redefined the *Course* class then subclassed it to create the *Undergrad* class. I have added a parameter, which requires redefining the *___init___()* function. The *super()* function returns all of the parameters and methods of the parent class. The use of *super()* provides control over what is inherited by the child class from the parent. We will not explore all possible use cases here. I then define a new method called *printCourse2()*.

Once an instance of the *Undergrad* class is created, I can use both methods, since the *printCourse()* method was inherited from the parent class.

```
class Course:
    def __init__(self, subject, number, name):
        self.subject = subject
        self.number = number
        self.name = name
    def printCourse(self):
        print("Course is " + self.subject + " " + self.name + ", Code:  "+ str(self.number))

class Undergrad(Course):
    def __init__(self, subject, number, name, level):
        super().__init__(subject, number, name)
        self.level = level
    def printCourse2(self):
       print("Undergrad Course is " + self.subject + " "  + self.name + ". " + "Must be a " +

x = Undergrad("Spatial Analysys", 3209, "With Python", "for New students")
x.printCourse()
x.printCourse2()
```

You will not be required to created classes and subclasses in this course. However, it is important to understand this functionality of Python for making use of modules and libraries, as this is used extensively. For example, the PyTorch library, which is used for deep learning, makes extensive use of classes, and using it will require subclassing available classes.

Math Module

The functionality of Python is expanded using **modules**. Modules represent sets of code and tools and are combined into **libraries**. In this class, we will explore several modules or libraries used for data science including **NumPy**, **Pandas**, **matplotlib**, and **scikit-learn**. We will also explore libraries for geospatial data analysis including **GeoPandas** and **Rasterio**.

As an introduction to modules and libraries, we will now explore the **math module**. To use a module, it first needs to be **imported**. You can then use the methods provided by the module. When using a method from the math module, you must include the module name as demonstrated below.

```
import math

x = 4.318
print(math.cos(x))
print(math.sin(x))
print(math.tan(x))
print(math.sqrt(x))
print(math.log10(x))
print(math.floor(x))
```

You can also provide an alias or shorthand name for the module when importing it by using the *as* keyword. This can be used to simplify code.

```
import math as m

x = 4.318
print(m.cos(x))
print(m.sin(x))
print(m.tan(x))
print(m.sqrt(x))
print(m.log10(x))
print(m.floor(x))
```

If you want to import each individual function from a module and not need to use the module name or alias name in your code, you can use the import syntax demonstrated below. This is generally best to avoid, especially if the module is large and/or has many functions.

```
from math import *

x = 4.318
print(cos(x))
print(sin(x))
print(tan(x))
print(sqrt(x))
print(log10(x))
print(floor(x))
```

You can also import individual functions or subsets of functions as opposed to the entire module.

```
from math import cos, sin
x = 4.318
print(cos(x))
print(sin(x))
```

Working with Files

1. Read Files

As a **data scientist** or **geospatial data scientist**, you need to use Python to work with and analyze files on your local machine.

First, a file or folder path can be assigned to a variable. On a Windows machine, you will need to either:

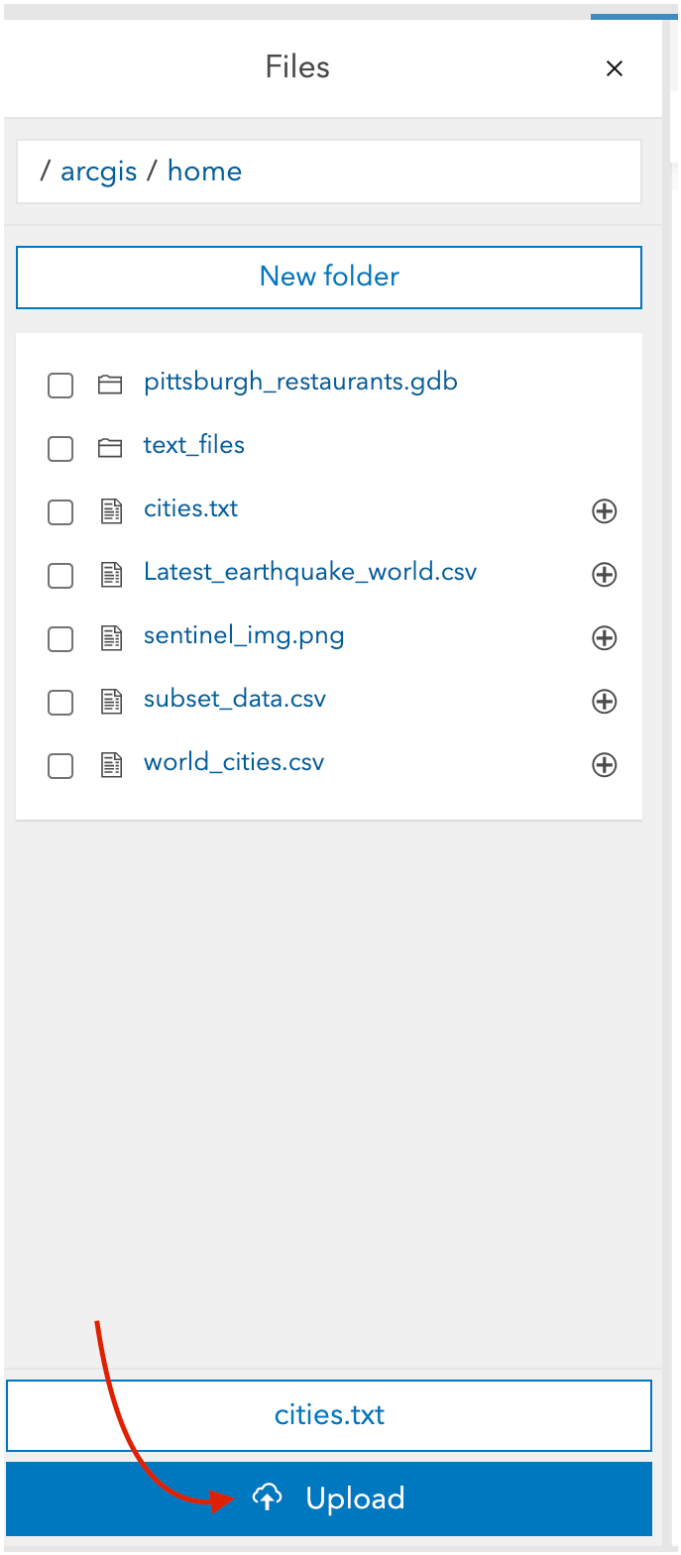
- Change the backslashes to forward slashes or
- Use the backslash escape character ahead of any backslash.

This is tricky depending of the operating system.

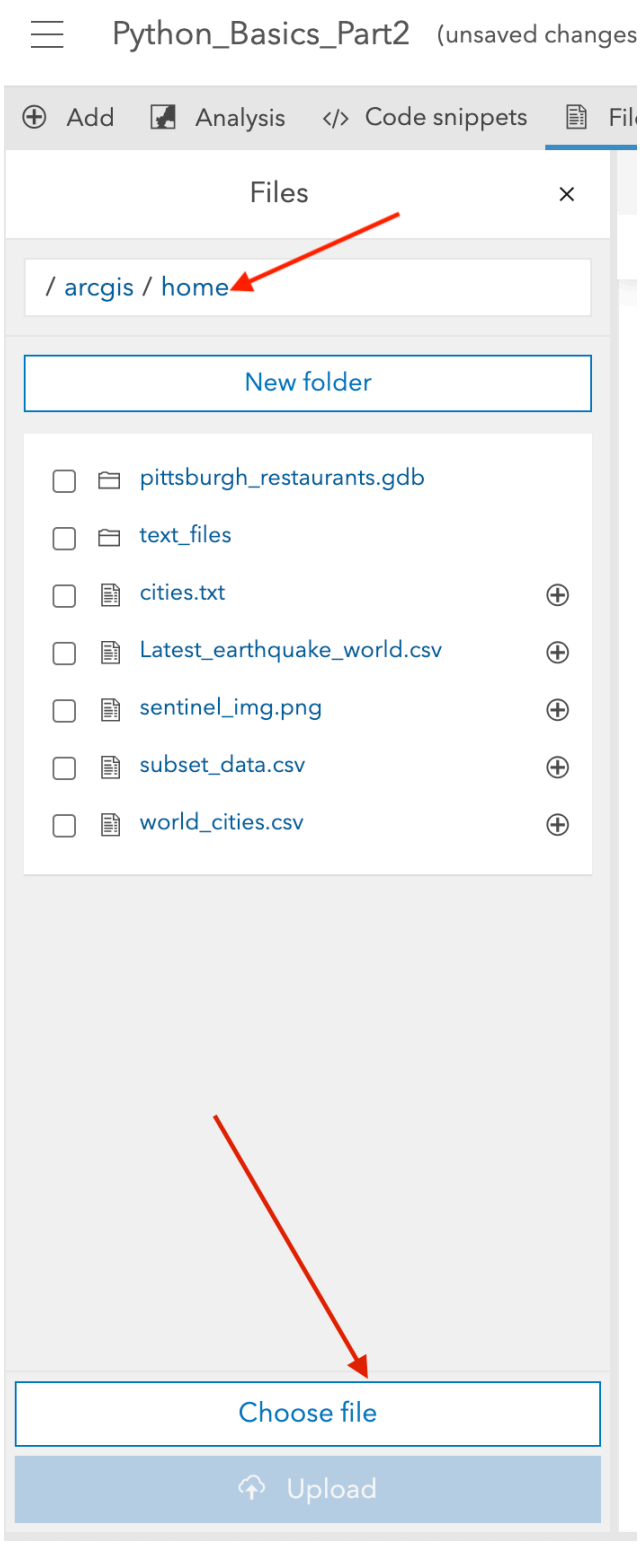
```
txt1 = "D:/data/text_files/t1.txt" #Must change backslash to forward slash
txt1 = "D:\\data\\text_files\\t1.txt" #Or, use the backslash escape character
```

For the following instructions you need to upload certain datasets to your Cloud GIS. In case you are working locally, the workflow is similar, you need to provide the appropriate path. For now we will upload the data into you Cloud GIS, so you can read it using the notebook hosted in ArcGIS Online.

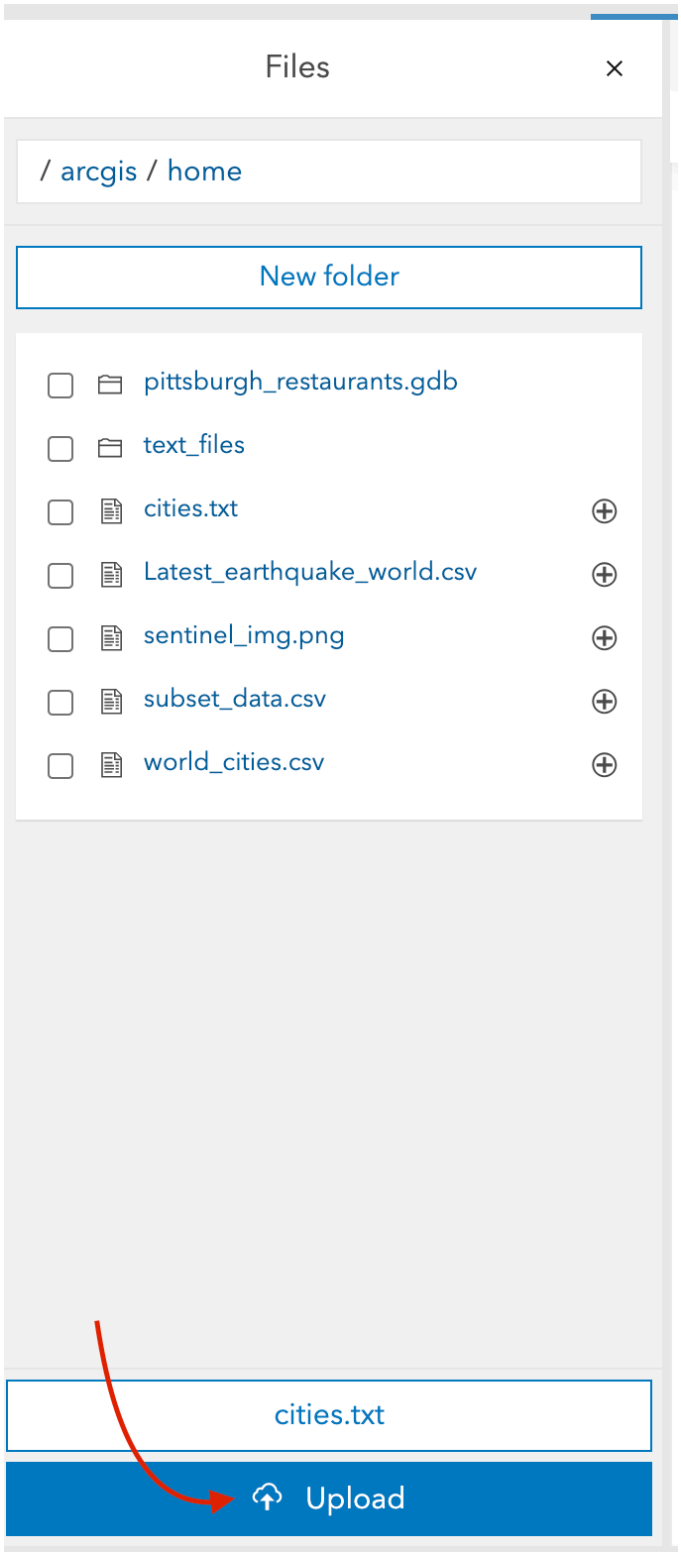
In this Notebook, click in Files.


Files
/ arcgis / home
New folder
pittsburgh_restaurants.gdb
text_files
cities.txt
Latest_earthquake_world.csv
sentinel_img.png
subset_data.csv
world_cities.csv
cities.txt
Upload

Download the **data** folder from Moodle, then click in **home**, then click in **Choose file** and select **cities.txt**


Python_Basics_Part2 (unsaved changes
Add
Analysis
Code snippets
Files
/ arcgis / home
New folder
pittsburgh_restaurants.gdb
text_files
cities.txt
Latest_earthquake_world.csv
sentinel_img.png
subset_data.csv
world_cities.csv
Choose file
Upload

Once you have chosen the file, then name will appear to confirm, now clic Upload.


Files
/ arcgis / home
New folder
pittsburgh_restaurants.gdb
text_files
cities.txt
Latest_earthquake_world.csv
sentinel_img.png
subset_data.csv
world_cities.csv
cities.txt
Upload

Now you have the **cities.txt** in your portal and now you can call the call., if you click in the **plus** symbol you will get a new cell from ArcGIS Notebook to help you to understand what is the correct way to call this dataset. For future instructions make your you have uploaded the required dataset, from Data folder included in Moodle.

To read a text file you can just use the module with, like this:

```
with open('/arcgis/home/cities.txt', "r") as f:
    contents = f.read()
    print(contents)
```

In the following example, we first import the **csv module**, which provides functionality for working with CSV files.

We then use the **with** statement to open the file "world_cities.csv" in read mode (r) and assign the file object to the variable csvfile.

We pass this file object to the csv.reader function to create a reader object that can be used to iterate over the rows of the CSV file.

Inside the with block, we loop over each row in the CSV file using a for loop, and print out each row using the print function.

Note that each row is represented as a list of strings.

Now, upload the **world_cities.csv** file, using the same process we described earlier.

```
import csv

with open('/arcgis/home/world_cities.csv', "r") as csvfile:
    reader = csv.reader(csvfile)
    for row in reader:
        print(row)
```

Specific modules or libraries will allow you to read in and work with specific types of data. For example, in the code below you are using **Pandas** to read in a comma-separated values (CSV) file as a Pandas DataFrame. We will discuss **Pandas** in a later part of this module.

In case you did not notice we use the keyword **import** to literally import the functionally of an external package that requires previous installation. For now we can import it without any issue. In case you need to import a new module that has not been included in your initial setup, you can still install it first, then make the import.

```
import numpy as np #Import numpy package, but then we said as np just for quick reference lat
import pandas as pd #Import pandas package, but then we said as pd just for quick reference l
# Sometime get the rigth path is tricky, so before entering to the function, you can add a pr
cities_df = pd.read_csv('/arcgis/home/world_cities.csv', sep=",", header=0, encoding="ISO-885
cities_df.head(10)
```

You can also use other modules like **matplotlib** to read and plot external files like an image, like this:

```
# importing required libraries
import matplotlib.pyplot as plt
import matplotlib.image as img

# reading the image
testImage = img.imread('/arcgis/home/sentinel_img.png')

# displaying the image
plt.imshow(testImage)
```

Working with Directories

Instead of reading in individual files, you may want to access entire lists of files in a directory. The example below demonstrates one method for accomplishing this using the **os** module and **list comprehension**. Specifically, it will find all TXT files in a directory and write their names to a list.

Only the file name is included in the generated list, so I use additional list comprehension to add the full file path and generate a new list.

```
import os

direct = '/arcgis/home/text_files'

files = os.listdir(direct)
files_txt = [i for i in files if i.endswith('.txt')]
print(files_txt)

txtlst = [direct + s for s in files_txt]
print(txtlst)
```

The code below demonstrates three other methods for reading in a list of TXT files from a directory. The first method uses the *listdir()* method from the **os** module, the second uses the

walk() method form the **os** module (which allows for recursive searching within subdirectories), and the last method uses the **glob** module.

You will see many other examples in this course of how to read files and lists of file names.

```
from os import listdir

def list_files1(directory, extension):
    return (f for f in listdir(directory) if f.endswith('.' + extension))

from os import walk

def list_files2(directory, extension):
    for (dirpath, dirnames, filenames) in walk(directory):
        return (f for f in filenames if f.endswith('.' + extension))

from glob import glob
from os import getcwd, chdir

def list_files3(directory, extension):
    saved = getcwd()
    chdir(directory)
    it = glob('*.' + extension)
    chdir(saved)
    return it

direct = '/arcgis/home/text_files/'
method1 = list(list_files1(direct, "txt"))
method2 = list(list_files2(direct, "txt"))
method3 = list_files3(direct, "txt")
print(method1)
print(method2)
print(method3)
```

f-Strings

In Python, **f-strings** can be used to format printed strings or include variables within strings. This technique can be useful for generating well-formatted and useful print statements or dynamically using variables in printed strings.

In the first example, I am printing x but with formatting defined to round to two decimal places. In the next example, I multiply x by itself in the printed string. Note that f-strings

will begin with *f* followed by the statement in parenthesis. Variables or code will be placed in curly brackets, and formatting can be defined using syntax after a colon. In the first example, ":2f" indicates to round to two decimal places.

In the third example, I am calling x in a statement while in the fourth example I am using the *.upper()* method to convert the string to all uppercase in the printed statement. Lastly, I have edited the *enumerate()* example above with an f-string to print the country name and assigned index in the for loop.

Throughout this course, you will see examples of f-strings for providing better formatted and/or more interpretable print output.

```
x = 0.123456789
print(f'The value is {x:.2f}')
x = 6
print(f'{x} times 2 is equal to {x*x}')
x = "blue"
print(f'My favorite color is {x}.')
x = "blue"
print(f'My favorite color is {x.upper()}.')

countries = ["Belgium", "Mexico", "Italy", "India"]
for index, country in enumerate(countries):
    print(f'The index for {country} is {index}.')
```

What's next

With these two notebooks(Part No1, and Part No2) you got a comprehensive list of components that you now can use to write python code. Now it is just a matter of practice and more practice.

Initially you will think this is extremely complicated or long, but with the exercises you will realised that is actually pretty simple.

Like I said before, if you have any particular question aks the available TA in the room.

Well done, now you have covered the basics for python it is time to PRACTICE a bit with less guidance.

Open the **Exercises_PythonBasics** and complete all the challenges there.

Data Sources

This is a list of web portals where you can access open and authoritative **geospatial data** for the UK and Scotland. These sources can be used to download shapefiles, connect to live web services, and enrich your **ArcGIS Online** projects with meaningful local datasets.

---

1. Scottish Spatial Data Infrastructure (SSDI)

The official portal for discovering and accessing spatial datasets from Scottish public bodies.

Data Available: - Administrative boundaries - Environmental and natural heritage data - Planning and infrastructure - Marine and coastal datasets - Data formats: Shapefiles, GeoJSON, WMS, WFS

---

2. Scotland's Environment Web

A partnership platform providing environmental datasets and interactive maps.

Data Available: - Land cover and land use - Air and water quality - Biodiversity and habitats - Climate and emissions - Tools: Map viewers, WMS services, downloadable shapefiles

---

3. Spatial Hub (Improvement Service)

Aggregates and publishes spatial data provided by all 32 Scottish local authorities.

Data Available: - Planning applications - Housing land audits - School catchments - Local development plans - Data formats: Shapefiles, WMS, GeoJSON (registration may be required)

---

4. UK Government Data Portal (data.gov.uk)

The central open data portal for the UK government.

Data Available: - Transport networks - Health and social care - Demographics and census - Crime and safety - Environment and energy - Formats: CSV, GeoJSON, Shapefiles, APIs, WMS/WFS services

---

5. Ordnance Survey OpenData

The UK's national mapping agency providing a range of open and premium geographic datasets.

Data Available: - OpenMap Local (general-purpose vector mapping) - OS Open Roads, OS Open Rivers - Boundary-Line (administrative boundaries) - Access via: Downloads, APIs, and ArcGIS-ready formats

---

6. National Records of Scotland (NRS) Geography

Provides the official statistical geographies for Scotland.

Data Available: - Data zones and Intermediate Zones - Census output areas - Health boards, local authorities - Formats: Shapefiles, GeoJSON

---

7. Office for National Statistics (ONS) Geography

Geospatial portal from the ONS offering boundary data and census geography.

Data Available: - Statistical geographies (LSOA, MSOA) - Census 2011 and 2021 boundaries - Parliamentary constituencies - Downloadable in ESRI Shapefile and GeoPackage formats

---

8. DEFRA Data Services Platform

UK Government's portal for environment-related data and services.

Data Available: - Flood risk zones - Agricultural land classification - River networks and water quality - Waste and recycling facilities - Access via: Shapefiles, APIs, WMS/WFS

---

9. OpenStreetMap (Geofabrik UK Extracts)

Extracts from OpenStreetMap for Great Britain, including Scotland.

Data Available: - Buildings, highways, land use, points of interest - Routable and editable map data - Formats: .osm.pbf, shapefiles (via tools like osmconvert or QGIS plugins)

---

10. Edinburgh GeoPortal

A geospatial data repository from Edinburgh with open datasets.

Data Available: - Local and global environmental data - Terrain and elevation - Land cover and vegetation indexes - Datasets relevant for climate change, ecology, and earth observation

---

11. Glasgow GeoPortal

A geospatial data repository from Glasgow with open datasets.

Data Available: - Local and global environmental data - Terrain and elevation - Land cover and vegetation indexes - Datasets relevant for climate change, ecology, and earth observation

---

12. ArcGIS Living Atlas (UK content)

ESRI's curated collection of geographic information, including UK-specific content.

Data Available: - Demographics, base maps, boundaries - Real-time environmental data - Accessible directly from ArcGIS Online for instant use

---

13. ArcGIS Living Atlas (UK content)

ESRI's curated collection of geographic information, including UK-specific content.

Data Available: - Demographics, base maps, boundaries - Real-time environmental data - Accessible directly from ArcGIS Online for instant use

---

14. Urban Big Data Centre

Urban Big Data Centre is a dynamic national research hub and data service, championing the use of smart data to inform policymaking and enhance the quality of urban life.

Data Available: - Transport and Mobility, Housing and property, Labor Market, Environment.

Tips for students

- Many of these platforms offer **shapefiles**, **WMS** or **ArcGIS REST endpoints**, which can be added directly to your **ArcGIS Online** web map.
- Make sure to always **cite the data source** in your apps or reports.
- For reproducibility, **record the download date** and dataset version.
- Use **filtering and geoprocessing tools** in ArcGIS Online to tailor data to your study area.

Troubleshooting Guide

With Python and in particular with many new ways to use your computer, create folder and scripts things can get messy and very confusing, this is very normal and it is part of the process. The first thing is do not get frustrated or trying all sort of things without understanding what is the root of the issue. So you need to think systematically and then find out the solution. Here I have listed a few potential and common issues you might find. So first take all of this before escalating your issue to the lecturer or the IT support team.

Before Seeking Help

You should complete this checklist:

- ☐ Miniconda is installed and `conda --version` works
- ☐ Environment was created without errors
- ☐ Environment shows `(gg3209)` when activated
- ☐ Verification script runs successfully
- ☐ Jupyter Lab starts without errors

Class Support

1. **First**: Check this troubleshooting guide
2. **Second**: Ask a classmate (compare outputs)
3. **Third**: Post your issue in the MS Teams channel of this course:
    - Your operating system (Windows/macOS)
    - Exact error message
    - Commands you ran
    - Output from verification script

Standardized Error Reporting

When reporting problems, always include:

```
# Run these commands and include output
conda info
conda list geopandas
python --version
jupyter --version
```

Issue 1: "conda: command not found"

This is the most common issue for beginners.

Windows Solution:

```
# Option 1: Use the correct command prompt
# Search for "Anaconda Prompt" in Start Menu if available
# Or reinstall Miniconda ensuring PATH is added

# Option 2: Manually add to PATH
set PATH=%PATH%;C:\Users\%USERNAME%\miniconda3\Scripts
set PATH=%PATH%;C:\Users\%USERNAME%\miniconda3
```

macOS Solution:

```
# Add to PATH temporarily
export PATH="$HOME/miniconda3/bin:$PATH"

# Add to PATH permanently
echo 'export PATH="$HOME/miniconda3/bin:$PATH"' >> ~/.bash_profile
source ~/.bash_profile

# For zsh users (macOS Catalina and later)
echo 'export PATH="$HOME/miniconda3/bin:$PATH"' >> ~/.zshrc
source ~/.zshrc
```

Issue 2: Environment Creation Fails

Common causes and solutions:

```
# Solution 1: Clean conda cache
conda clean --all

# Solution 2: Update conda first
conda update conda

# Solution 3: Try creating environment with explicit solver
conda env create -f environment.yml --solver=classic

# Solution 4: Check internet connection and try again
# Large downloads may timeout on slow connections
```

Issue 3: Different Python Versions

All students must have Python 3.10 for consistency.

```
# Check your Python version
python --version

# If incorrect, remove environment and recreate
conda env remove --name gg3209
conda env create -f environment.yml
```

Issue 4: Package Conflicts During Installation

This indicates environment file issues:

```
# Solution: Use mamba for faster, more reliable solving
conda install mamba -n base -c conda-forge
mamba env create -f environment.yml
```

Issue 5: Jupyter Lab Won't Start

Consistency check:

```
# Ensure environment is activated
conda activate gg3209

# Verify Jupyter installation
```

```
jupyter --version

# If missing, reinstall
conda install jupyter jupyterlab -c conda-forge

# Start Jupyter Lab
jupyter lab
```

Issue 6: Import Errors Despite Successful Installation

Environment activation problem:

```
# Always activate environment first
conda activate gg3209

# Check which Python you're using
which python     # macOS/Linux
where python     # Windows

# Should show path to conda environment, not system Python
```

Issue 7: PDF Generation Not Working

LaTeX installation issues:

```
# Verify LaTeX installation
pdflatex --version

# If missing, install manually:
# Windows: Download MiKTeX from https://miktex.org/
# macOS: Install MacTeX from https://tug.org/mactex/

# Test PDF conversion
jupyter nbconvert --to pdf test_notebook.ipynb
```

Emergency Reinstallation

If all else fails, sometimes it is better and quicker run a complete clean installation:

```
# Remove environment
conda env remove --name gg3209

# Clean all caches
conda clean --all

# Recreate environment
conda env create -f environment.yml
```

Additional Resources

Use the following instructions as a guide for extra resources and better familiarity with working with Python. In case you want to manage your python environment, export your outcomes to PDF, and get extra learning resources.

Environment Management - Useful Commands

```
# List all environments
conda env list

# Activate environment
conda activate gg3209

# Deactivate environment
conda deactivate

# Update all packages in environment
conda update --all

# Install additional package
conda install package-name

# Remove environment
conda env remove --name gg3209
```

Updating the Environment

```
# Update environment from file
conda env update -f environment.yml --prune
```

Exporting Your Environment

```
# Export current environment
conda env export > my-environment.yml
```

PDF Generation

You are required to submit your work as report to MMS in a PDF format, and most of the outcomes created in this modules are Jupyter Notebooks, so you will need to export them as PDF. This environment includes comprehensive PDF generation capabilities for creating professional scientific documents from Jupyter notebooks. This includes:

- **LaTeX-based PDF generation** for high-quality academic formatting
- **Web-based PDF conversion** for quick exports
- **Scientific document formatting** with proper citations and references
- **Professional layout templates** for reports and dissertations

Testing PDF Generation

After setting up your environment, test the PDF generation capabilities:

1. Open a terminal or command prompt windows.
2. Run `python TestingPDFCapabilities.py`.

Converting Notebooks to PDF

Method 1: Command Line (Recommended)

```
# Activate environment
conda activate gg3209

# Convert notebook to PDF via LaTeX
jupyter nbconvert --to pdf your_notebook.ipynb

#If the last one failed, try
jupyter nbconvert --to webpdf --allow-chromium-download your_notebook.ipynb
```

```
#If both fail, check the options provided in the troubleshooting section for PDFs

# Convert with custom template, optional
jupyter nbconvert --to pdf --template classic your_notebook.ipynb

# Convert with bibliography support, optional.
jupyter nbconvert --to pdf --template article your_notebook.ipynb
```

Method 2: Jupyter Lab Interface (also recommended)

1. Open your notebook in Jupyter Lab
2. Go to **File > Export Notebook As > WebPDF**
3. Choose export options
4. Save the generated PDF

Method 3: Programmatic Conversion (for advanced users)

```
import nbformat
from nbconvert import PDFExporter

# Read notebook
with open('your_notebook.ipynb', 'r') as f:
    nb = nbformat.read(f, as_version=4)

# Convert to PDF
pdf_exporter = PDFExporter()
pdf_exporter.template_name = 'classic'
(body, resources) = pdf_exporter.from_notebook_node(nb)

# Save PDF
with open('output.pdf', 'wb') as f:
    f.write(body)
```

Professional PDF Features

Creating Professional Reports

Template Structure

To create a template notebook with:

```
# Report template structure
"""
# Title: Professional Spatial Data Science Report
## Author: Your Name
## Date: Current Date
## Abstract
Brief description of the analysis...

## 1. Introduction
Research question and objectives...

## 2. Methodology
### 2.1 Data Sources
### 2.2 Analytical Methods
### 2.3 Software and Tools

## 3. Results
### 3.1 Descriptive Statistics
### 3.2 Spatial Analysis
### 3.3 Hotspot Analysis

## 4. Discussion
Interpretation of results...

## 5. Conclusions
Summary and recommendations...

## References
Academic citations...

## Appendices
Additional materials...
"""
```

Professional Visualization for PDF

```
import matplotlib.pyplot as plt
import seaborn as sns

# Configure matplotlib for high-quality PDF output
plt.rcParams['figure.dpi'] = 300
plt.rcParams['savefig.dpi'] = 300
plt.rcParams['font.size'] = 12
plt.rcParams['axes.titlesize'] = 14
plt.rcParams['axes.labelsize'] = 12
plt.rcParams['xtick.labelsize'] = 10
plt.rcParams['ytick.labelsize'] = 10
plt.rcParams['legend.fontsize'] = 11
plt.rcParams['figure.titlesize'] = 16

# Use professional color palette
sns.set_palette("husl")

# Create publication-ready figures
fig, ax = plt.subplots(figsize=(8, 6))
# Your plotting code here
plt.tight_layout()
plt.savefig('figure.png', dpi=300, bbox_inches='tight')
plt.show()
```

Troubleshooting to PDF Generation

Common Issues and Solutions

Issue: LaTeX not found

```
# Solution: Install LaTeX distribution
# Windows: Download MiKTeX or TeX Live
# macOS: Install MacTeX
conda install texlive-core texlive-latex-extra
```

Issue: 500 : Internal Server Error

Issue when you try to use Export as PDF and you get errors relates to `nbconvert failed:`

```{bash}
pip install 'nbconvert[webpdf]'

jupyter nbconvert --to webpdf --allow-chromium-download YouJupyterNotebook.ipynb
#This will create a PDF in the same folder of your Jupyter Notebook., Or use the optiopn incl
```

Issue: PDF conversion fails

```
# Solution: Use alternative method
jupyter nbconvert --to html your_notebook.ipynb
# Then use browser to print to PDF
```

Issue: Figures not appearing in PDF

```
# Solution: Ensure figures are saved inline
%matplotlib inline
import matplotlib.pyplot as plt
plt.rcParams['savefig.format'] = 'png'
plt.rcParams['savefig.bbox'] = 'tight'
```

Issue: Long code cells breaking across pages

```
# Solution: Use page breaks and cell splitting
from IPython.display import display, HTML
display(HTML('<div style="page-break-before: always;"></div>'))
```

Best Practices for PDF Generation

1. **Use consistent formatting** throughout your notebook
2. **Include descriptive markdown** for each analysis step
3. **Add figure captions** and table descriptions. One of the most common issue when you create a PDF.
4. **Test PDF generation** regularly during development
5. **Include proper citations** and references
6. **Optimize images** for print quality (optional)

This guide was created for the GG3209 Spatial Analysis with GIS students at SGSD University of St Andrews. For questions or suggestions, please create an issue in this book repository. 2025