# Python Practice Session

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# Objectives

- Understand the basics of Python software.
- Write a Python package for the Fibonacci sequence.

## Notes on Writing Python

- Case-sensitive, e.g., `Print` is not the same as `print`
- Leading spaces are significant (and should always be spaces, **NOT** tabs).
  - The number of spaces is up to you, but you should be consistent.
  - e.g., if you choose to indent two spaces, you should always use two space.
- The type of brackets, braces, etc. are significant.

```
1 # This is a comment.
2 # It gives the reader context.
3 print('hello world')
4 for i in [1, 2, 3]:
5     print(i)
```

## What is a Notebook?

- Examples are Colab and Jupyter.
- Notebooks are single files (`*.ipynb` extensions).
- Notebooks are designed for singe use.
  - ▸ E.g., tutorials, data analysis, rapid prototyping.
- NOT intended for reuse, or further development.
  - ▸ Can force it if you really want to...

## What is a Module?

- Python software has three flavors: modules, packages, and libraries.
- A module is a single *.py file.
- Modules are building blocks of packages and libraries.
- All the actual effort goes into writing modules.

# What is a Package?

- Packages are modules distributed together.
- Directory, __init__.py file, and *.py files.
- Name of the directory will be the name of the package.
- The __init__.py file is usually empty, but is essential because that's how Python determines your directory is a package.
- The *.py files are plain text and are where you put the code.

## What is a Library?

- Libraries are packages that are distributed together.
- Libraries are usually distributed individually so the terms stop here.
- We won't worry about how to develop a library.

## What is a project?

- Disclaimer, may not be a standardized term.
- Modules, packages, and libraries are "just the code."
- Good software also "infrastructure", e.g., documentation, tests, etc.
- We call everything together the "project."

# Fibonacci Sequence

- 0, 1, 1, 2, 3, 5, 8, ...
- $F_i = F_{i-2} + F_{i-1}$
- Our goal: write a package for computing $F_i$.

# Setup: Project Structure

- Let's call our project Fibby
- In terminal, start by making a directory called fibby.
  - Note it is lowercase to avoid file system gotchas.
- What is the terminal command for creating fibby?

# Setup: Project Structure

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  - ▶ `mkdir fibby`

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- In terminal, start by making a directory called `fibby`.
  - ▶ Note it is lowercase to avoid file system gotchas.
- What is the terminal command for creating `fibby`?
  - ▶ `mkdir fibby`
- All of our project files will live inside this directory.
- Practice: add `fibby/README.md` with contents: `Welcome to Fibby!`
- N.b., paths for this tutorial are given relative to the first `fibby` directory you made.

# Setup: Package Structure

- Within a project, Python modules are separated from infrastructure.
- Python modules for a package are stored in a single directory.
- Python uses the directory name as the name of the package.
- Unfortunately this leads to a very common pattern where the name of the project and the name of the package are the same.
- I.e., add a directory `fibby/fibby`

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- How do we tell Python that `fibby` is a package?

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- How do we tell Python that `fibby` is a package?
  - Add a file `__init__.py` to `fibby/fibby`.

- Create a file
  `fibby/fibby/fibonacci.py`.
- For now, just worry about
  computing $F_0 = 0$ and $F_1 = 1$.
- Write a function which takes $i$
  and returns $F_i$.

# Setup: Making the `fibby` Module

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  `fibby/fibby/fibonacci.py`.
- For now, just worry about
  computing $F_0 = 0$ and $F_1 = 1$.
- Write a function which takes $i$
  and returns $F_i$.

```
1  def fibonacci(i):
2      if i == 0:
3          return 0
4      if i == 1:
5          return 1
```

# Does Fibby work?

- What is the command to run Fibby?

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  ▷ `python3 fibonacci.py`
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## Does Fibby work?

- What is the command to run Fibby?

  ▷ `python3 fibonacci.py`
  ▷ `python3 fibonacci.py 0`
  ▷ `python3 fibonacci.py 1`

- This was a trick question. We only **defined** a function `fibonacci`. We never called it.
- Very common error...

# Calling Fibby.

- Add a call to `fibonacci`.
- Now how do we run it?

```python
1  def fibonacci(i):
2      if i == 0:
3          return 0
4      if i == 1:
5          return 1
6
7
8  fibonacci(0)
```

# Calling Fibby.

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# Calling Fibby.

- Add a call to `fibonacci`.
- Now how do we run it?

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- Again common error. Remember computers do **exactly** what you ask them to do.

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- Add a call to fibonacci.
- Now how do we run it?

  ▸    `python3 fibonacci.py`

- This was a trick question. We called the function, but didn't **print** the value.
- Again common error. Remember computers do **exactly** what you ask them to do.
- Correct code.
- How would we print $F_1$?

```python
1 def fibonacci(i):
2     if i == 0:
3         return 0
4     if i == 1:
5         return 1
6
7
8 print(fibonacci(0))
```

## Development Notes

- When you develop software you typically don't call your function, class, etc. in the module you define it in.
- We did this just as a "sanity check."
- Want to "separate concerns."
- (Go ahead and delete the `print(fibonacci(0))` line).
- Modern software development is test-driven. So lets write a test.

```
1 def fibonacci(i):
2     if i == 0:
3         return 0
4     if i == 1:
5         return 1
```

# Testing Fibby

- Create `fibby/tests`
- Create
  `fibby/tests/__init__.py`
- Create
  `fibby/tests/test_fibonacci.py`
- Run: `pytest` in `fibby` directory.
- At this point

```python
from fibby.fibonacci import fibonacci

assert fibonacci(0) == 0
assert fibonacci(1) == 1
```

# Notes on Structure

- We now have a bare-bones Python project.
- There's actually theory behind why projects are set up this way.
- If you try to get creative you will likely run into import errors.
- Until you are a Python expert, just stick with this pattern.

```
1  # Project Structure
2  # project_name/
3  # |--- package_name/
4  # |    |---__init__.py
5  # |    |---module1_name.py
6  # |    |---module2_name.py
7  # |--- tests/
8  # |    |--- __init__.py
9  # |    |--- test_module1_name.py
10 # |    |--- test_module2_name.py
```

- Our code only works for $i \leq 1$.
- Let's generalize it.
- Many possible implementations.
- General tip: get something that works first.
- Easy implementation: fill a list.

# Towards Arbitrary $F_i$

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- Let's generalize it.
- Many possible implementations.
- General tip: get something that works first.
- Easy implementation: fill a list.

```python
1  def fibonacci(i):
2      seq = [0, 1]
3
4      while len(seq) <= i:
5          seq.append(seq[-2] + seq[-1])
6
7      return seq[i]
```

## Performance

- Our implementation is not optimal.
- How bad do you think it is?
- Try asking for $F_{10} = 55$

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- $F_{5008} = 182 \cdots$

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- $F_{5008} = 182 \cdots$
- $F_{25000} =$??? (string conversion error)

# Performance: Lesson

- Pro tip: do NOT pre-maturely optimize your code.
- Our naive Fibonacci code can compute $F_{25000}$ in under a second!
- Code readability/maintainability should be the priority for the first pass.
- Only start optimizing code when it becomes a bottleneck.

# Documentation

- I recommend adding documentation as the last step before a PR.
  - ▸ If you add it too early, you'll often find that you need to change it because you added/removed a parameter, changed the type of a parameter, etc.
- In Python we document functions with "docstrings".
- Docstrings are free-form, but in science we usually follow "numpydoc" style.
  - ▸ https://www.geeksforgeeks.org/python-docstrings/

```python
def fibonacci(i):
    '''
    This is a summary line. It should be
    about a sentence long.

    This is the extended description.
    Note that the entire docstring is
    indented as far as the quotes we used.

    Parameters
    ----------
    i : int
        Which fibonacci number you want.
        i == 0 is 0. i == 1 is 1.
        i == 2 is 1. i == 3 is 2. Etc.

    Returns
    -------
    int
        The requested fibonacci number
    '''

    # Code would go here
```

# Generalizing

- While real-world problems are harder, they're tackled basically the same way.
- Write code units (e.g., function, class, libraries) for each task.
- Test the code units as you write them.
- If code unit gets too big, split it.
- Document before committing.

# Misc.

- Software engineering is ultimately a soft science.
- Should this be a function? A class? A library? Subjective.
- Ultimately, any solution that gets the right answer (for the right reasons) is "correct".
- Easier to test small code units. I recommend erring on the side of too small, rather than too large.
- A lot like "showing your work" in math. Each code unit shows a step.
- As you get more comfortable you can start "skipping steps."

# Debugging

- In practice, most of coding is debugging.
- Something you get better at with practice.
- Need to trace the logic of the program and see where if fails.
- Usually introduced through `print` statements.
  - Basically print values until you find the first one that is wrong.
- Tools called "debuggers" that can do this (and more) for you.

# Practice

- Fibonacci sequence prototypical example of recursion.
  - ▹ Recursion: Function `fibonacci` calls itself.
- Goal: write the call for $F_i$ in terms of the calls for $F_{i-2}$ and $F_{i-1}$.
- Hint: in terminal `ctrl + c` kills the current running process.
  - ▹ Common recursion problem is running forever because function just keeps calling itself.

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