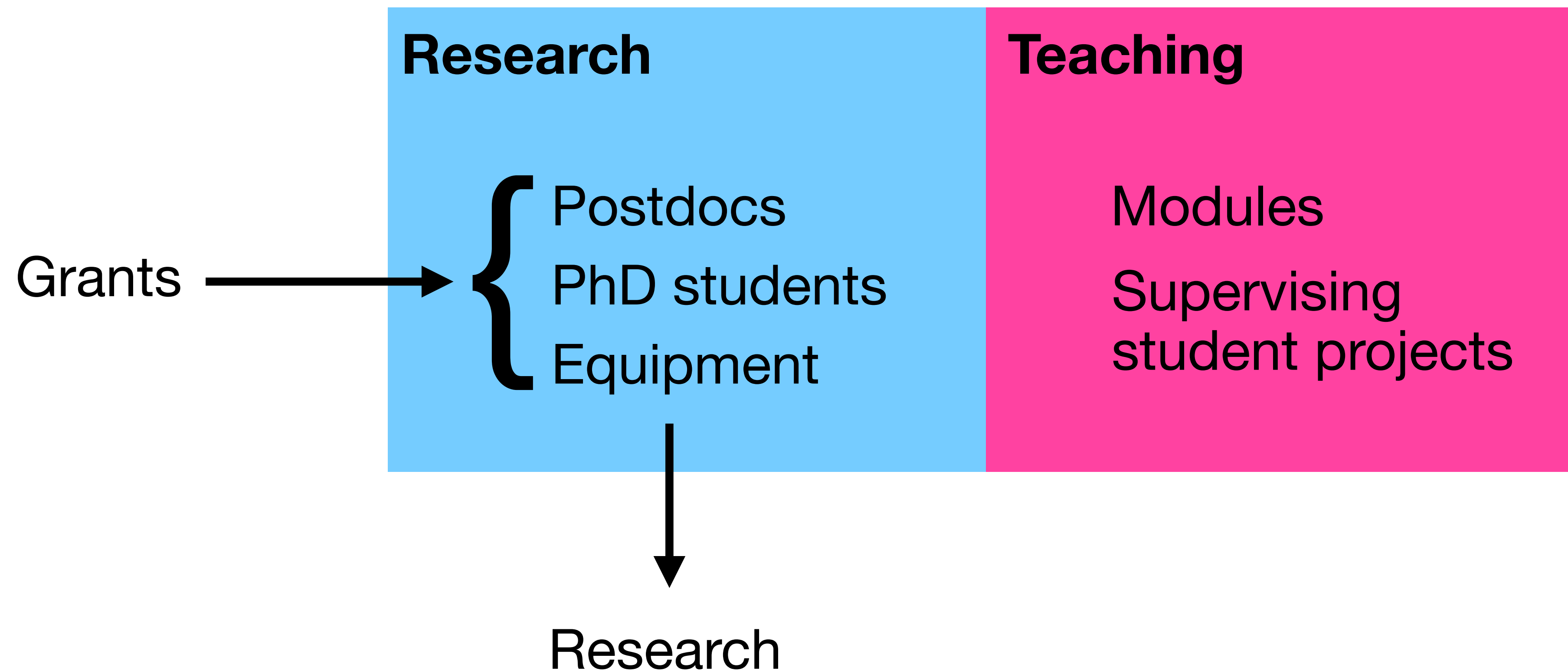


Learning **how** to think mathematically and computationally

Algorithmic approaches to mathematics
2025-2026

Dhruva V. Raman

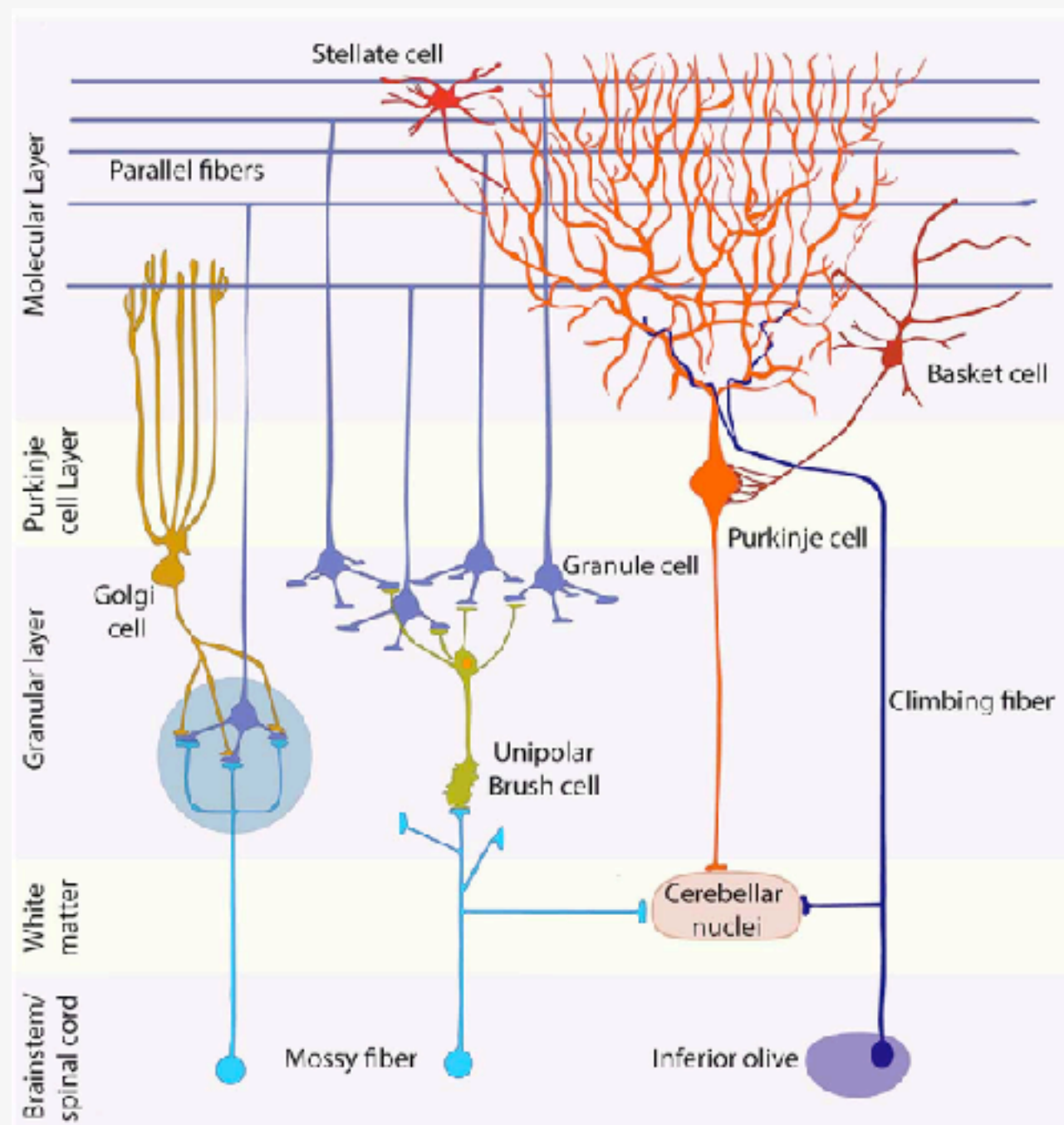
Who are we? A lecturer's life



Dhruva / Sir / Professor

(Don't worry about correct pronunciation)

Design principles in biological systems



What about **this** design makes **this** system good for function?

Can we better understand function from design?

Dhruva

XXX raises your risk of cancer by 20%!!!

How can we constructively
break the conclusions of
statistical models

*“Lies, damned lies,
and statistics”*

Who are you?

Diverse academic backgrounds.
That's ok!

Making a spectrum of friends will help
you academically and personally

- Introduce yourself to neighbours each lecture
- Don't sit in the same places each week!

Today

Why do this course?

How to do this course?

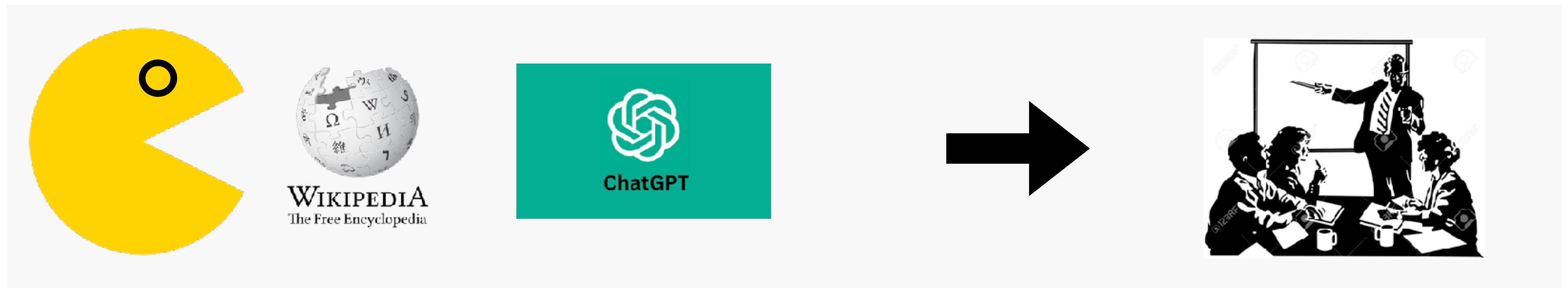
What should I know
outside this course?

Learning goal: how to **digest** maths



Learning goal: how to **digest** and **use** maths

21st century life

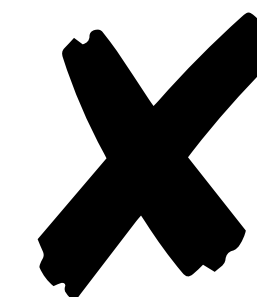


How to learn/communicate/use/think
with mathematical concepts



By learning maths!

Learn maths
all of it!

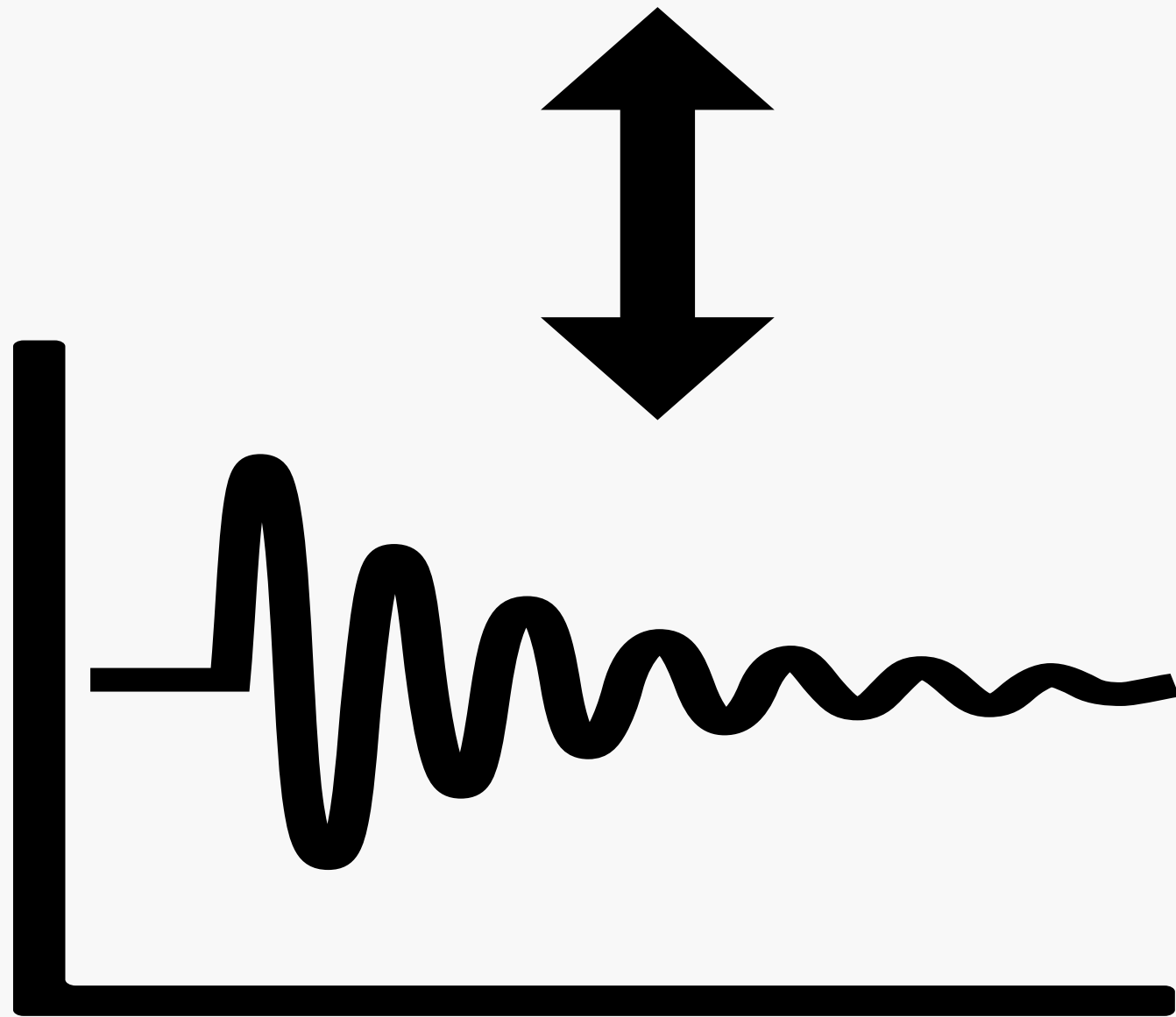


Requirement 1: Language

Definition of a continuous function

$\forall \epsilon \in \mathbb{R}^+ : \exists \delta > 0 \text{ s.t.}$

$\|x - y\|_2 < \delta \Rightarrow \|f(x) - f(y)\|_2 < \epsilon$



Mathematics

Reading/writing using
LaTeX notation

Appreciating/using
good grammar

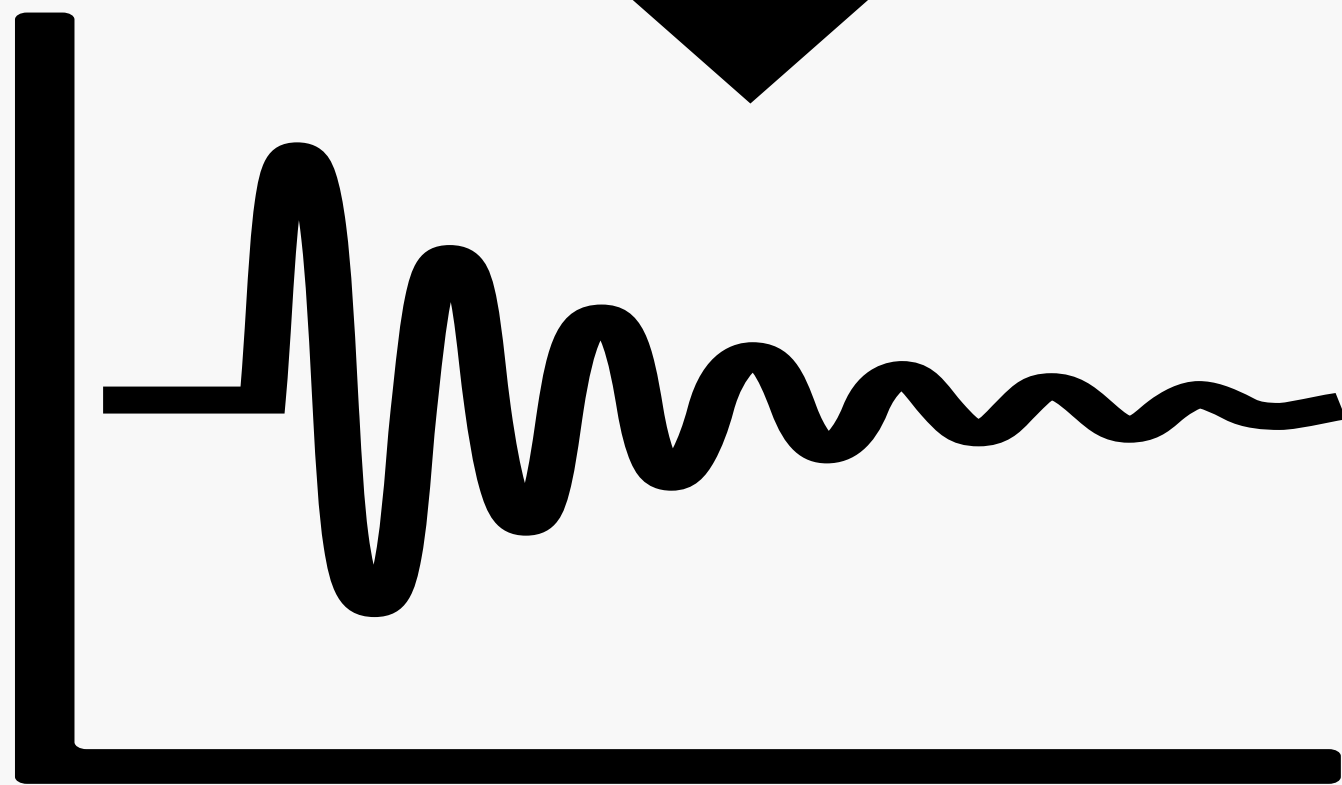
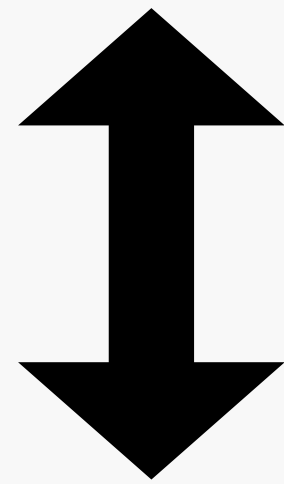
[https://kapeli.com/cheat_sheets/
LaTeX_Math_Symbols.docset/Contents/Resources/
Documents/index](https://kapeli.com/cheat_sheets/LaTeX_Math_Symbols.docset/Contents/Resources/Documents/index)

Requirement 1: Language

Definition of a continuous function

$\forall \epsilon \in \mathbb{R}^+ : \exists \delta > 0 \text{ s.t.}$

$\|x - y\|_2 < \delta \Rightarrow \|f(x) - f(y)\|_2 < \epsilon$



Mathematics + programming

Reading/writing using
LaTeX notation

Appreciating/using
good grammar

[https://kapeli.com/cheat_sheets/
LaTeX_Math_Symbols.docset/Contents/Resources/
Documents/index](https://kapeli.com/cheat_sheets/LaTeX_Math_Symbols.docset/Contents/Resources/Documents/index)

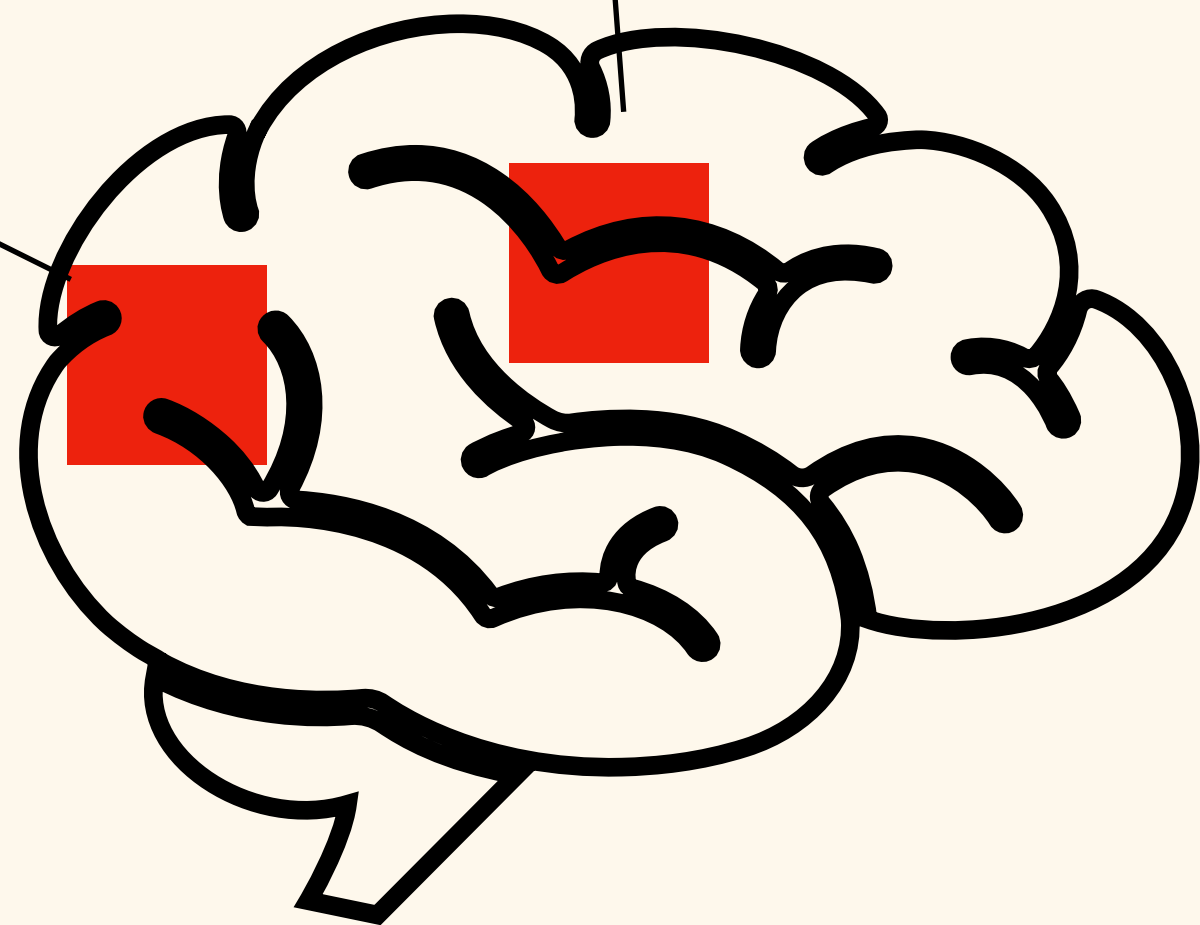
Requirement 2:

Unifying mathematical and computational thinking

Bad

Mathematics

Programming



Good

They help each other



Requirement 3: unlearning

The confidence to experiment, play, distrust and ask questions!

(Bad) school -level
understanding

Memorise formulae
and recipes

Purpose is to
pass exam

Show off knowledge
when communicating

Requirement 3: unlearning

The confidence to experiment, play, distrust and ask questions!

(Bad) school -level understanding

Memorise formulae and recipes

Purpose is to pass exam

Show off knowledge when communicating



Understanding enough to **use**

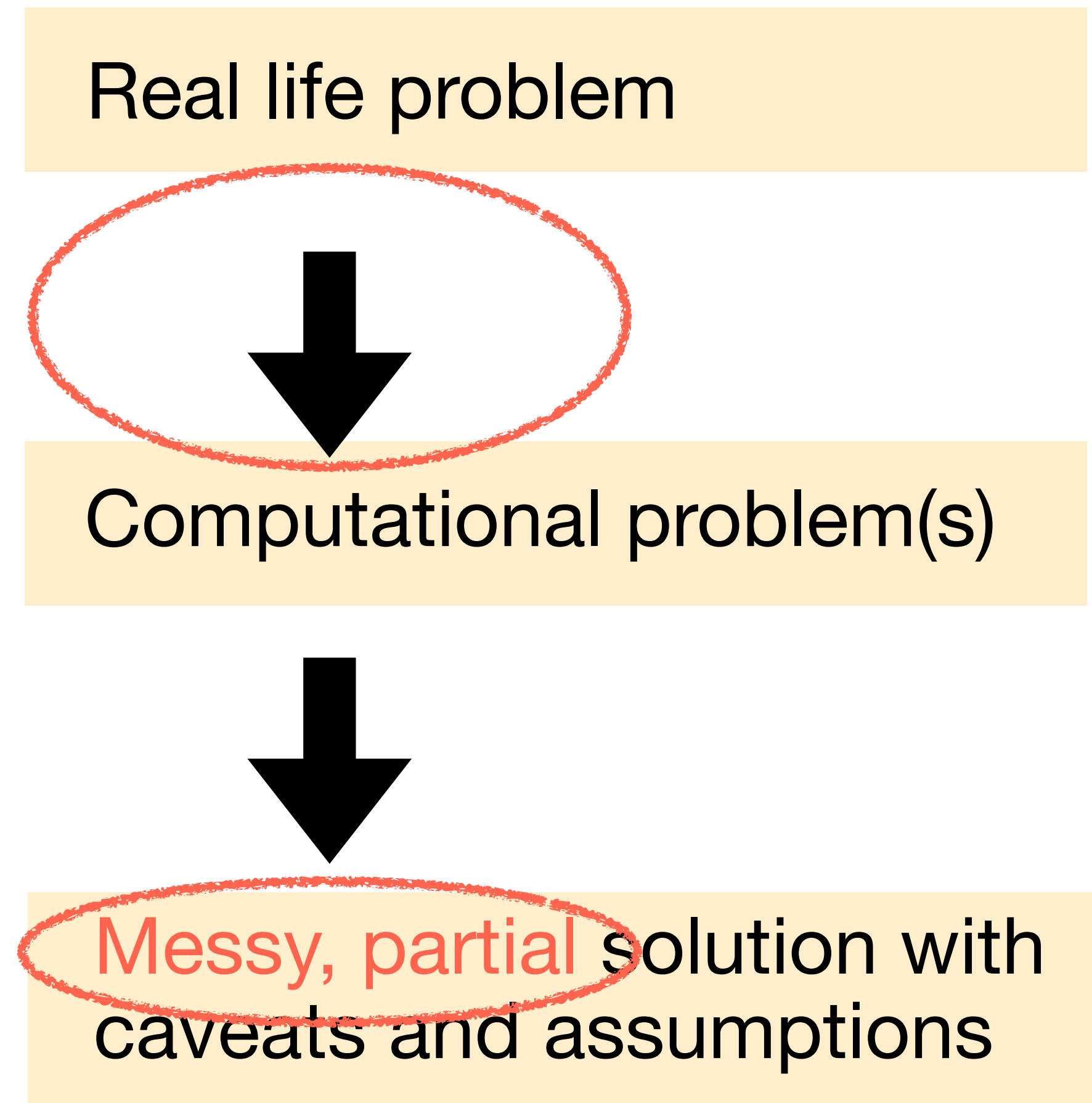
When is it **wrong**?
What's the **point**?

Can I use it for something else?
Can I break it?

Can I explain it **simply**?

Requirement 4:

Maths as a **pragmatic** tool for complex systems



Requirement 5

Surveying the landscape



I don't know what things
I don't know



Mathematical tools to
solve my problem?

Which tools?

Course structure

Fast survey of main useful topics in applied mathematics/engineering

Giving you the knowledge to teach yourself more advanced topics if/when you need to



Scientific computing

Linear Algebra

Probability

Dynamical
systems

Optimisation theory

Worried?

Look at the prerequisites on canvas

Basic, necessary school-level maths:

<https://canvas.sussex.ac.uk/enroll/KYHLP9>

Today

Why do this course?

How to do this course?

What should I know
outside this course?

**This is not a
spectator sport!!!!**

Maths is not a spectator sport!!!

Attend all lectures

Read and understand all
worksheets

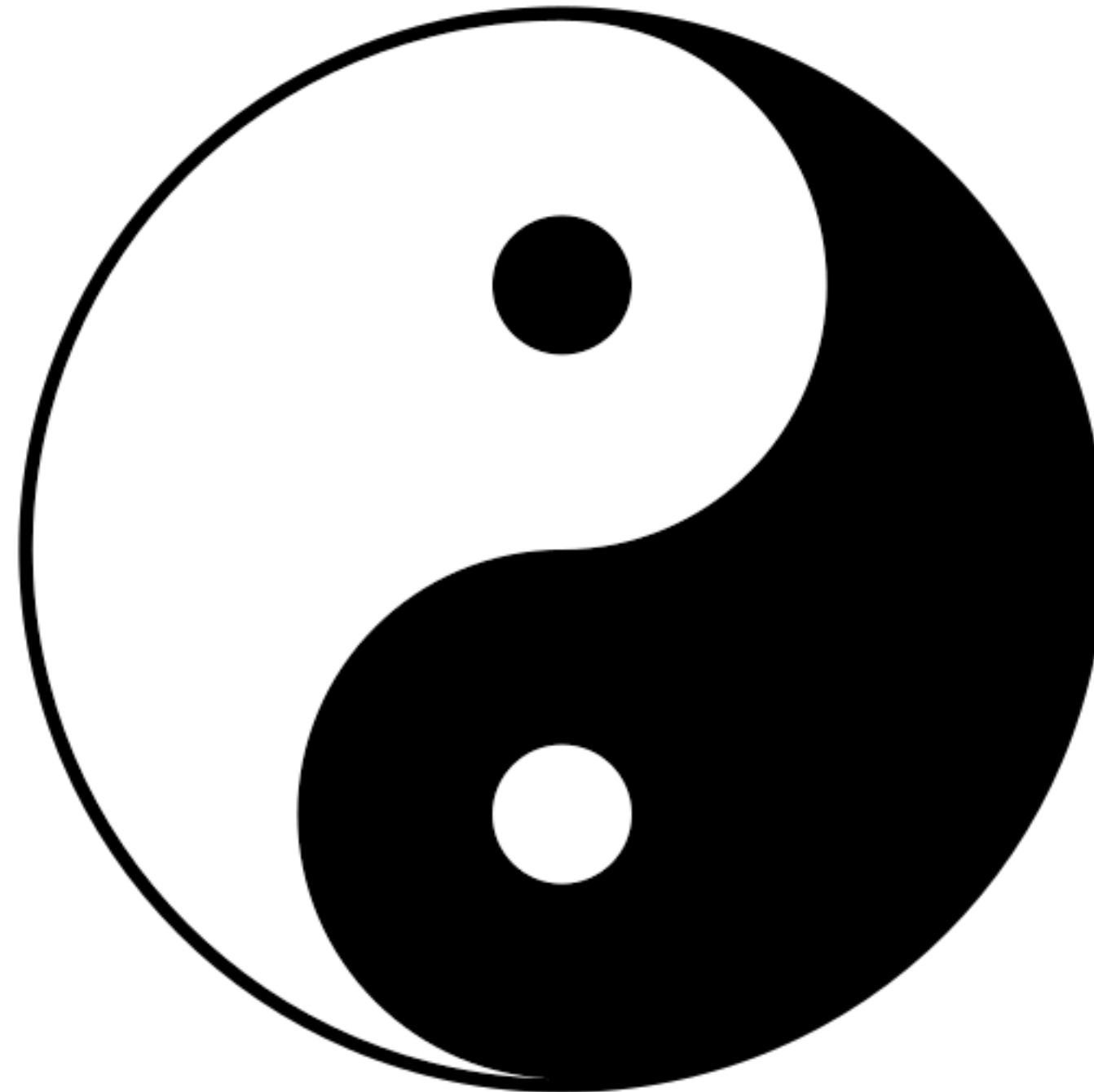
Revise all concepts



FAIL THE EXAM

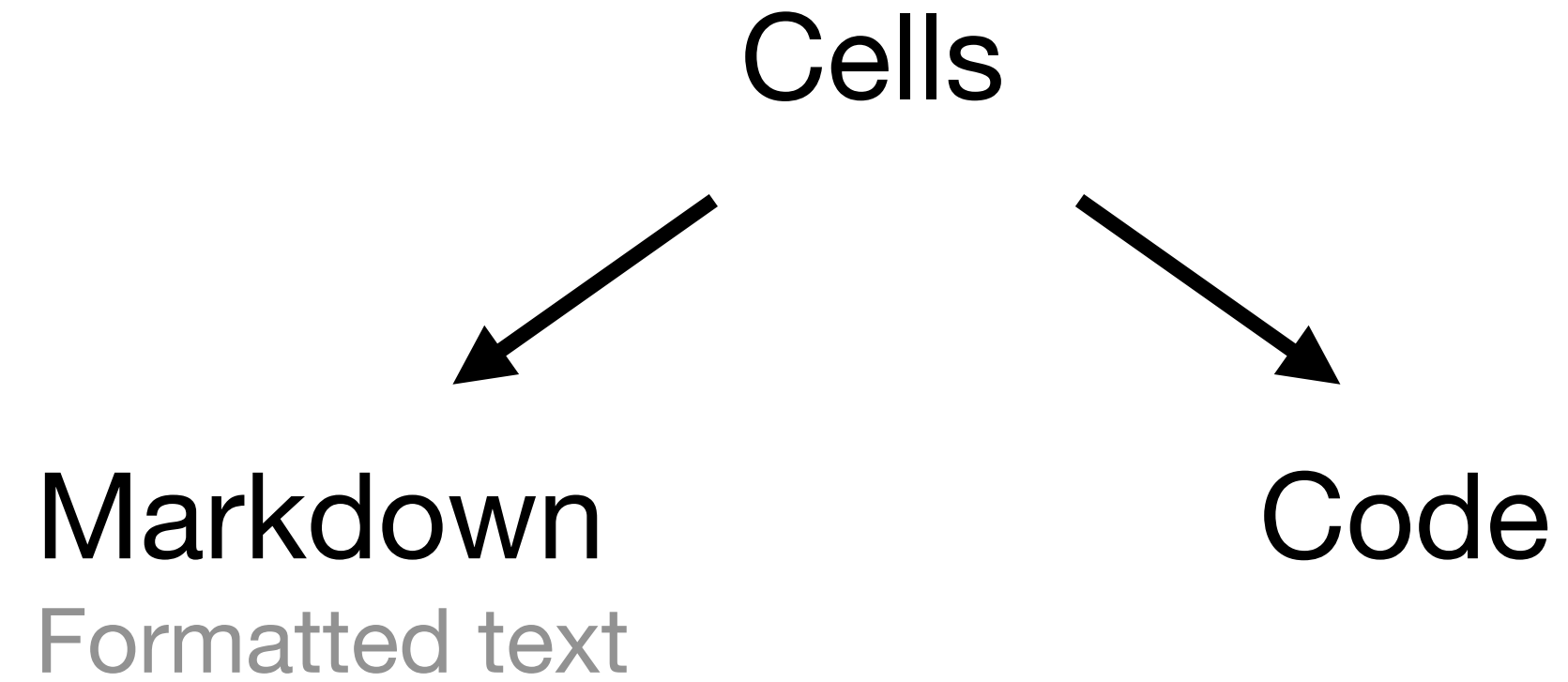
Course structure

Notebooks
that you fill in



(Lectures)

A notebook is a personal 'code' diary



www.markdownguide.org/basic-syntax/

Web browser (e.g. Chrome)

Week 1 questions.py

Output of cell 1

Cell 1

Output of cell 2

Cell 2



Parallel notebooks in Python and Julia

Python

Less mathematical background

Best for quickly learning the essential mathematical concepts

Julia

Mathematical background

Best for improving programming and problem-solving

Similar to Python at this level

Bilingual is better

Code

```
1 import marimo as mo
import numpy as np
3 import matplotlib.pyplot as plt
```

Markdown output

Welcome to MCMCS!!

Week 1: Assignment, logic, and functions

```
1 # **Welcome to MCMCS!**
```

markdown

BEFORE YOU START!

- The Python strand of this course runs on [Marimo](#) notebooks. What you are reading! They are similar to the Jupyter notebooks you will be using in other courses, but more suited for the type of questions you will be solving on this course as they are [stateless](#). We'll learn about this in lectures.
- You will **save time** in the long run if you spend time **now** understanding how marimo notebooks work, and how to build, modify and save them.
- You can start with the guide [here](#). The quickstart guide for using the editor is [here](#).
- Going through the tutorials is quick and useful. These are example notebooks that you read through and modify. You just have to enter (at the terminal): `marimo tutorial intro`.

...for the introductory tutorial. Other useful tutorials are: `intro`, `dataflow`, `ui`, `markdown`, `plots`, `layout`, `fileformat`, `markdown-format`, `for-jupyter-users`.

The `for-jupyter-users` tutorial is particularly useful if you have some experience with jupyter notebooks (which you will be using in other classes)

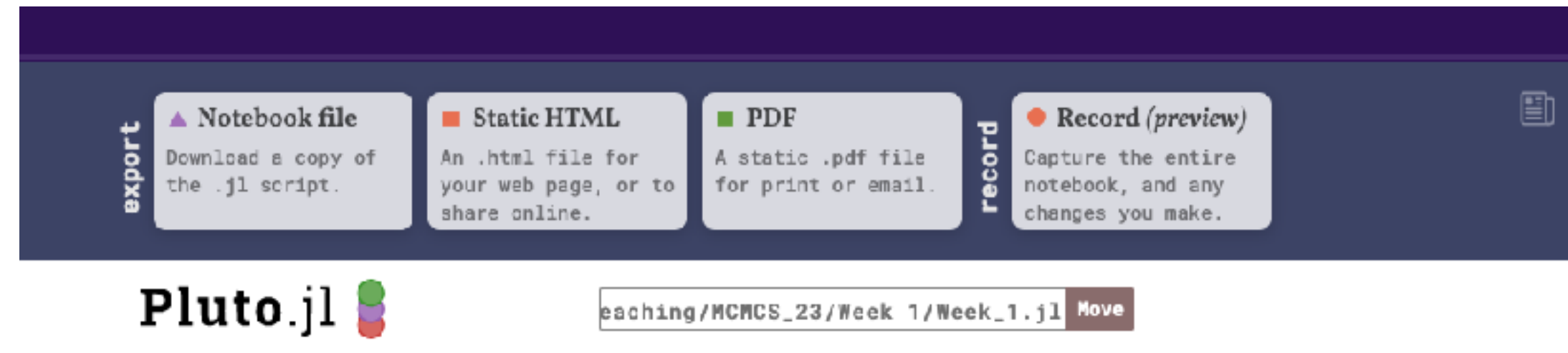
Don't worry if you don't understand everything about how notebooks operate immediately! You will learn as you do!

```
1 # BEFORE YOU START!
```



markdown

Markdown input
(hidden)



Markdown output →

Welcome to MCMCS!!

Week 1: Assignment, logic, and functions

Goals of this worksheet

- Start getting comfortable with using basic Julia to express maths.
- Familiarise yourself with Pluto notebooks and LaTeX shortcuts for writing mathematical symbols.
- Introduction to the type system in Julia. (All languages have one, implicitly or explicitly)

First make sure you can...

- add your own code / text boxes.
- enable and hide visibility of the code by clicking the eye on the top left corner of each code box.
- modify existing code / text. EG what you are reading right now. Look at how I made this box textual: md followed by three quotation marks, and ended by three quotation marks. This creates a text box where you can write in markdown. Google markdown syntax, eg [here](#). Notice that you can freely alter this box itself! **Try it**
- use the live docs to help you see the definition of the code you are writing
- modify and save the worksheet
- write maths using dollar signs and LaTeX syntax, e.g. by modifying the equation below. Notice the dollar signs have to be touching the maths...no spaces! Learning LaTeX syntax will be an ongoing exercise, **necessary for the exam**, over the next few weeks.

$$x^2 + y^2 = \frac{a}{b} + \int_1^3 \gamma(t) dt$$

- note that **comments** can be made in code blocks using the comment icon #. Comments don't affect the code. You will see commented code below.

Markdown cells (Julia/Python)

Assignment

Think of the concept of a **noun** in English (or any other human language). It binds a word to a concept. For instance, when you read *Dhruva* (a proper noun), you might conceptualise me. When you read *person*, you might conceptualise the more abstract concept of an arbitrary human being.

When programming, we create our own nouns (others are already provided by the programming language). These are known as **variables**. They link an expressible, readable name (e.g. `x`) to a julia object (e.g. the `Float64` number: `1.0`).

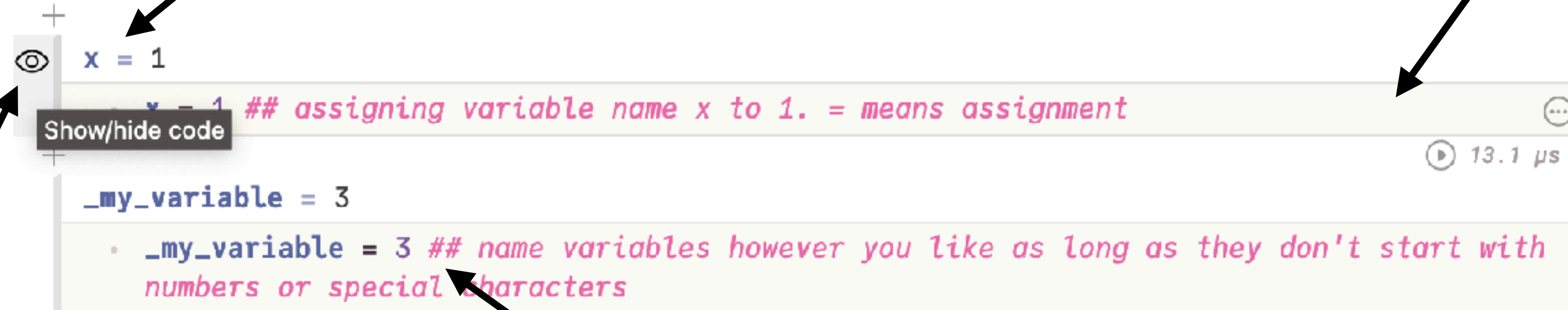
```
• md"""
• # Assignment
•
• Think of the concept of a noun in English (or any other human language). It binds
a word to a concept. For instance, when you read Dhruva (a proper noun), you might
conceptualise me. When you read person, you might conceptualise the more abstract
concept of an arbitrary human being.
•
• When programming, we create our own nouns (others are already provided by the
programming language). These are known as variables. They link an expressible,
readable name (e.g. x) to a julia object (e.g. the Float64 number: 1.0).
• """
•
```

▶ 467 μs

Code blocks

Code outputs

Code cell



```
x = 1
```

x = 1 ## assigning variable name x to 1. = means assignment

```
_my_variable = 3
```

_my_variable = 3 ## name variables however you like as long as they don't start with numbers or special characters

Set in/visible

“#” to add code comments

Annotate and save your notebooks!

How?

Inspect/modify the cells I have written!

Why?

Answer provided questions

Make your own course notes

Web browser (e.g. Chrome)

Week 1 questions.py

Output of cell 1

Cell 1

Output of cell 2

Cell 2



Why not Jupyter notebooks?

More elegant?

Force you to code in a
different style

Better for **interactive** graphs
and data analysis

Fewer bugs

Why not Jupyter notebooks?



Jupyter notebook

Output of cell 1

$X = 4$

Output of cell 2

$X = 5$

Code uses e.g. $X + 2$

Why not Jupyter notebooks?

Stateless notebook:

No top-to-bottom order

No ambiguity about variable values

Dependent cells refresh

Stateless notebook (Marimo/Pluto)

Code uses X



Output of cell 1

X = 4

Output of cell 2

X = 5

Code uses e.g. X + 2

Why not Jupyter notebooks?

Force you to code in a different style

My notebook

Week 1 questions.py

Output of cell 1

Small function that does something you repeat

Output of cell 2

Compose small functions to do a complicated task in few lines of code



Writing LaTeX in markdown

This is a nonsensical mathematical expression

$$\int_0^T \frac{a(t)}{b(t)} dt \in \mathbb{R}$$

- `[] e`

```
• md"""  
•  
• ##### This is a nonsensical mathematical expression  
•  
• $$\int_{0}^T \frac{a(t)}{b(t)} \mathrm{d} t \in \mathbb{R}$$  
•  
•  
• """
```

▶ 322 μs

<https://www.overleaf.com/>

....or download locally

(<https://typst.app/>)

< Typst File Edit View Help

Ag B I U H ≡ ≡ Σ <> @

☰

📖


?

⚙️

typst

Johanna's Typst > Space Mail

💬 ✓ − 100% +

 Share ⬇

```
1 #import "template.typ": *
2 #show: paper.with(
3   title: [Towards Swifter Interstellar Mail Delivery],
4   date: [May 17th, 2022],
5   ...
24 )
25
26 = Introduction Egon
27 Our concept suggests three ways that A-Mail can be best utilized.
28
29 - First is to reduce the probability of the failure of a space mission. This
    problem is known as the Mars problem and suggests problems with human
    communication.
30
31 - As A-Mails are written using pen and paper, no digital technology is needed for
    short and long distance communication. This suggests a possibility of reducing
    the communication monopoly currently held by an entity known as the "internet".
32
33 - High round-trip times required for communication between Mars and Earth inhibits
    successful human developments on the planet. In contrast, the delivery speed of
    an A-Mail can be determined through this simple formula:
34 $ v(t) = \lim_{t \rightarrow \infty} \int_1^t c \cdot \sqrt{t^2} \, dt $
35
36 #figure(
37   image("a-mail.svg"),
```

Towards Swifter Interstellar Mail Delivery

Johanna Swift
Delivery Institute

Egon Stellaris
Space Institute

Oliver Liam
Mail Institute

May 17th, 2022

Until there is a definitive answer to the mystery of the dead star,
please use the old postal system to submit your question and report
the location of missing letters to the P.I.

ABSTRACT

Recent advances in space-based document processing have enabled faster mail delivery between different planets of a solar system. Given the time it takes for a message to be transmitted from one planet to the next, its estimated that even a one-way trip to a distant destination could take up to one year. During these periods of interplanetary mail delivery there is a slight possibility of mail being lost in transit. This issue is considered so serious that space management employs P.I. agents to track down and retrieve lost mail. We propose A-Mail, a new anti-matter based approach that can ensure that mail loss occurring during interplanetary transit is unobservable and therefore potentially undetectable. Going even further, we extend A-Mail to predict problems and apply existing and new best practices to ensure the mail is delivered without any issues. We call this extension AI-Mail.

Reference: Johanna Swift, Egon Stellaris, Oliver Liam. Towards

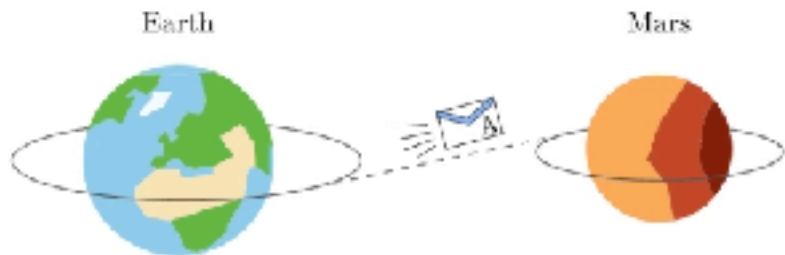


Figure 1: Visualization of the FTL Earth-to-Mars communication capabilities enabled by A-Mail.

- High round-trip times required for communication between Mars and Earth inhibits successful human developments on the planet. In contrast, the delivery speed of an A-Mail can be determined through this simple formula:

$$v(t) = \lim_{t \rightarrow \infty} \int_1^t c \cdot \sqrt{t^2} dt$$

Use the live docs

• `sum()`

▶ 67.0 μ s

Goals of this worksheet

🔍 Live Docs

📶 Status

sum

sum

```
sum(f, itr; [init])
```

Sum the results of calling function `f` on each element of `itr`.

The return type is `Int` for signed integers of less than system word size, and `UInt` for unsigned integers of less than system word size. For all other arguments, a common return type is found to which all arguments are promoted

Use the live docs

DOCUMENTATION

```
def sum(iterable: Iterable[_T], /) ->  
    Union[_T, int]
```

Return the sum of a 'start' value (default: 0) plus an iterable of numbers

When the iterable is empty, return the start value.
This function is intended specifically for use with numeric values and may reject non-numeric types.

/Users/dr360/Library/CloudStorage/Box-Box/Teaching/M

🔔 Reconnected

You have reconnected to an existing session.

```
1 import marimo as mo  
2 import numpy as np  
3 import matplotlib.pyplot as plt
```

```
1 sum()
```


<https://youtube.com/watch?v=Hgd2F2QNfEE>



Repeat before each lab

This is my notebook. There are many like it,
but this one is mine

My notebook is my best friend. It is my life.
I must master it as I must master my life.

Without me, my notebook is useless.
Without my notebook, I am useless

Course etiquette

Start the notebooks early

Annotate the notebooks massively

Don't give up!!!

Course etiquette

Use the padlet:

Attend labs
(attendance will be recorded)

Missing the labs?

Send excuses **during missed lab**

(Timed email)

Relaxed, creative, perseverance

Ironclad ego

Spend time on a question
without worrying

Ask naive questions

Playfulness

Maths is a game! Take breaks

Don't get in a hole: change tactics

How to collaborate and use the answers

Using answers when
completely stuck

Sharing approaches and
perspectives

Using answers when
mildly bored

Blindly copying



Doing it wrong?

The only person who gets
hurt is **you**



Asking questions

During/after the lecture

During seminars

Summary

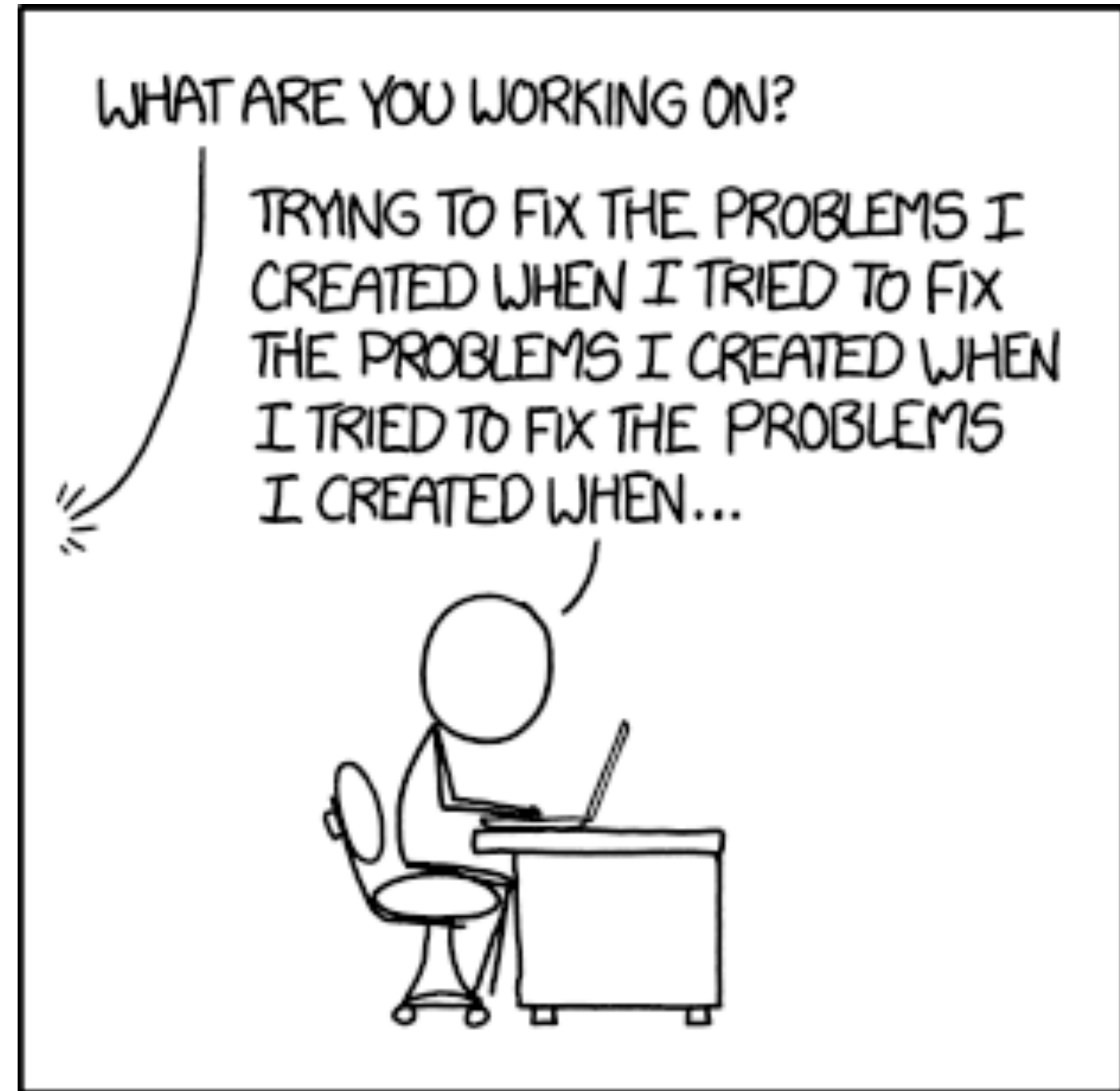
You learn when you're patient
and when you **have fun**

Do the notebooks
conscientiously

Ask questions and
talk to colleagues

Be proactive!!

The most important part of programming



Debugging

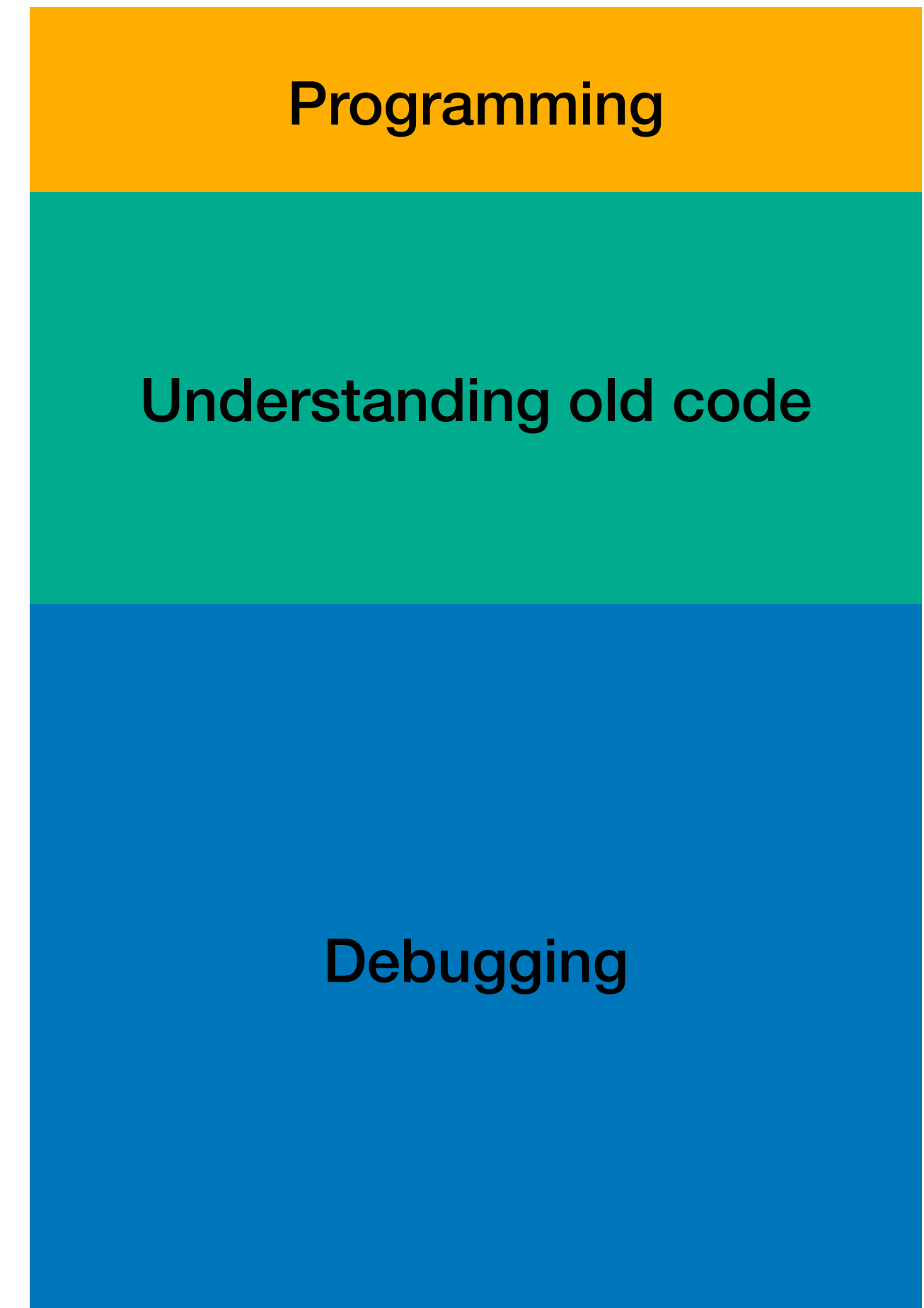
Good debugger

>

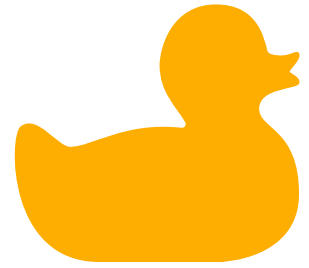
Good programmer

Comment all code
extensively

Future you will be
thankful



Debugging




Search

Rubber duck debugging

Article [Talk](#)

From Wikipedia, the free encyclopedia

 The Duck House Brighton
<https://www.theduckhousebrighton.online>

[Home | The Duck House Brighton | Rubber Duck Shop](#)

Welcome to The Duck House! Here you will find over 400 different types of imaginative **rubber ducks**. There's one for everyone! Browse our website or come and ...

[All Ducks](#)

There's a Rubber Duck for Everyone! Black Facebook Icon ...

[Most Popular](#)

There's a Rubber Duck for Everyone! · DC- Catwoman ...

[About Us](#)

At The Duck House you will find over four hundred different ...

[Special Occasions](#)

There's a Rubber Duck for Everyone! · Love Eco Rubber ...

[More results from theduckhousebrighton.online »](#)

Good programming is a **craft**

Good programmers are
always in high demand

Write code you're
proud of

Continuously
improve **style**

Use the padlet to ask questions

<https://uofsussex.padlet.org/draman2/questions-board-to0eux5irituizt4>

And to make lecture requests!

**Make sure you've read
the canvas/course
website info!**

Now...

Go through the Marimo learn notebooks
if you're unfamiliar with Python

<https://marimo-team.github.io/learn/>

Start familiarising with mathematical
notation on the cheatsheet

Then get working on notebook 1
(Python / Julia)

Today

Why do this course?

How to do this course?

**What should I know
outside this course?**

I'm jealous of my friend

Simple tools that work together.
Advanced furniture-making + DIY

Handiness

Literacy with tools allows for creativity,
nonstandard solutions and fixing things

Better quality more bespoke than IKEA /
builders but takes ages :(

**Mastery is
enjoyable**

My friend is jealous of me

Simple tools that work together. On a computer

Handiness

Literacy with tools allows for creativity, nonstandard solutions and fixing things

Mastery is enjoyable

Quicker and better than using monolithic tools!

What can I do on my setup?

What

Write/reuse/move/search/
visualise content and data

Where

Websites, slides,
documents, databases...

All my tools work together.

Not working / no functionality?
I can sort it

You should be “handy” with a computer

Slow and iterative process

Worth it for any computer-based job

<https://missing.csail.mit.edu/>

“The missing semester of your CS education”

Critical skills I won't teach you

Git

Touch typing

SQL (e.g. in marimo)

Modal editing
(Most tools allow
vim keybindings)

Confidence
using the shell