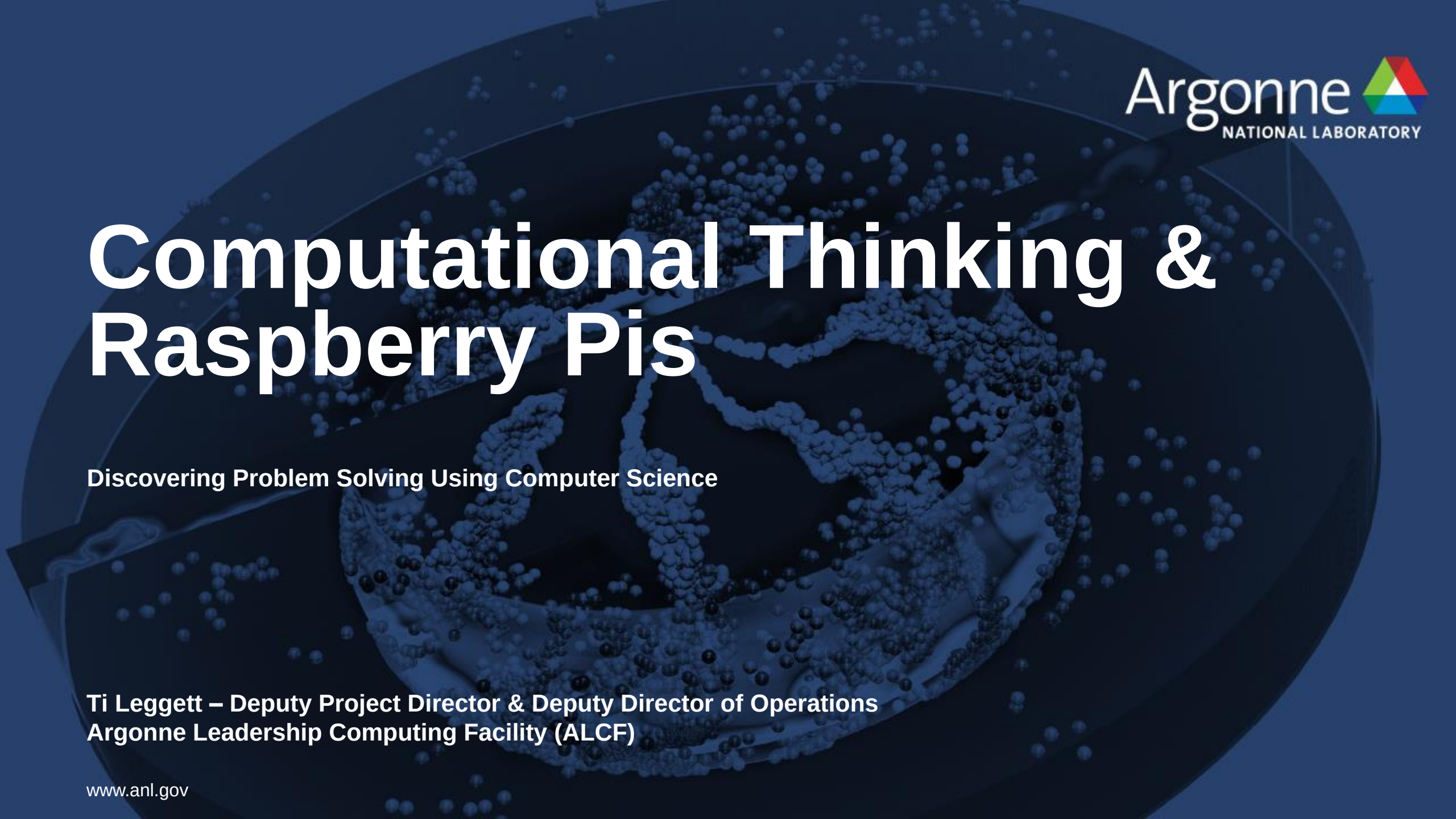


Computational Thinking & Raspberry Pis

Discovering Problem Solving Using Computer Science

Ti Leggett – Deputy Project Director & Deputy Director of Operations
Argonne Leadership Computing Facility (ALCF)

Why computational thinking?

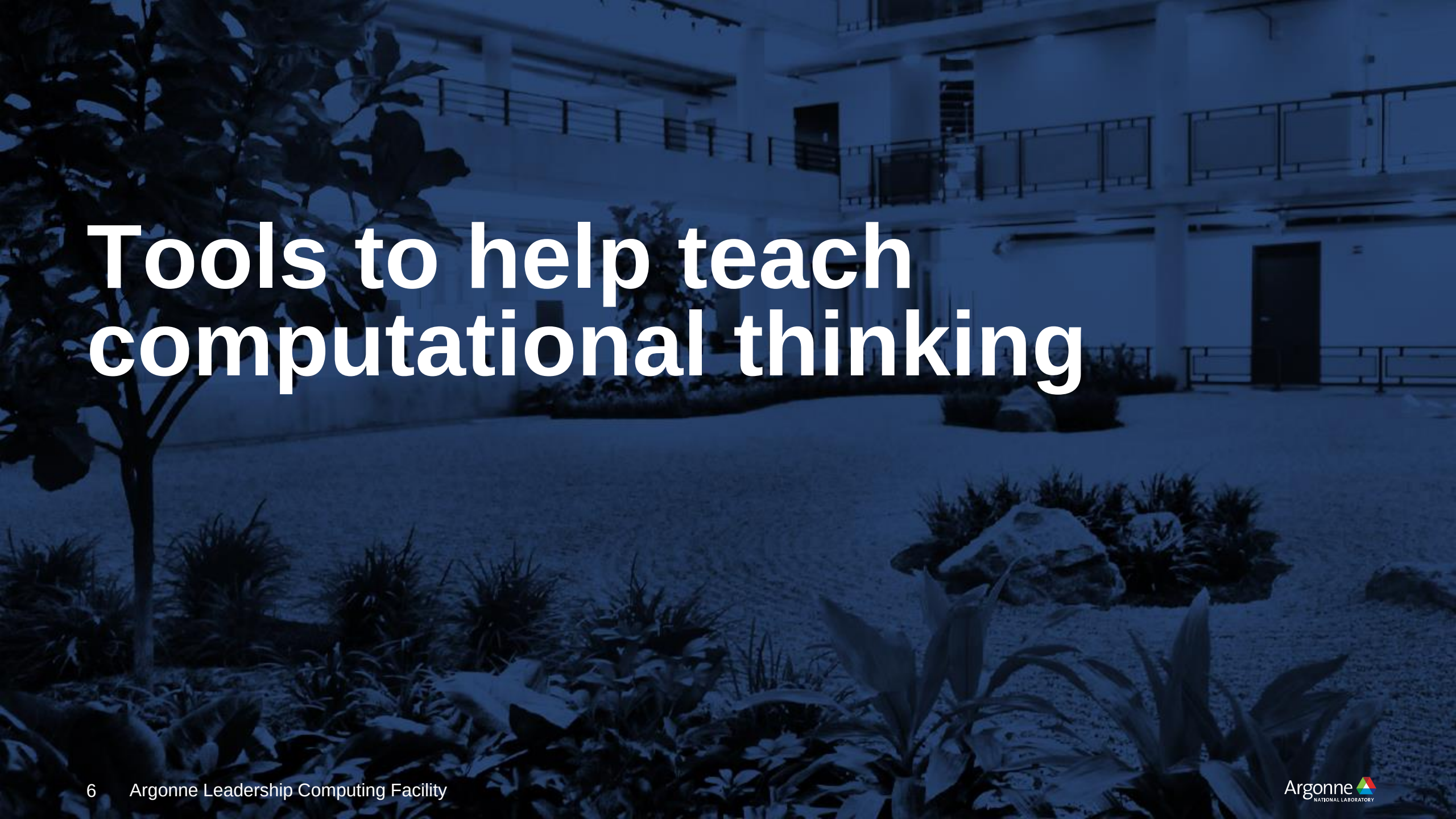
Problem Solving by Pattern Matching

- Critical skill, not just in computer science
- Break the problem down
  - What are you trying to solve?
  - What do you know/have?
  - Do you know what you don’t know?
    - How do you find out what you don’t know?
  - Do you notice any patterns?
    - After solution, can you simplify/optimize the solution further?

Examples

- Helping my son with math homework
- Assembling a wheelbarrow
- Building a house in Minecraft


My Story



Tools to help teach computational thinking

Software Resources

- **MIT Scratch**
  - http://scratch.mit.edu

Software Resources

- **MIT Scratch**
  - https://scratch.mit.edu
- **Code.org**
  - https://code.org

Software Resources

- **MIT Scratch**
  - https://scratch.mit.edu
- **Code.org**
  - https://code.org
- **Alice**
  - https://www.alice.org

What’s the difference?

- MIT Scratch
  - More open ended
  - Community based
- Code.org
  - Aligned with Common Core
  - Step by Step
  - Hour of Code
- Alice
  - Focuses more on visual and interactive
  - Not as widely used as other two

Hardware Resources

- Lab computers, laptops, & tablets

Hardware Resources

- **Lab computers, laptops, & tablets**
- **Arduinos**
  - https://www.arduino.cc

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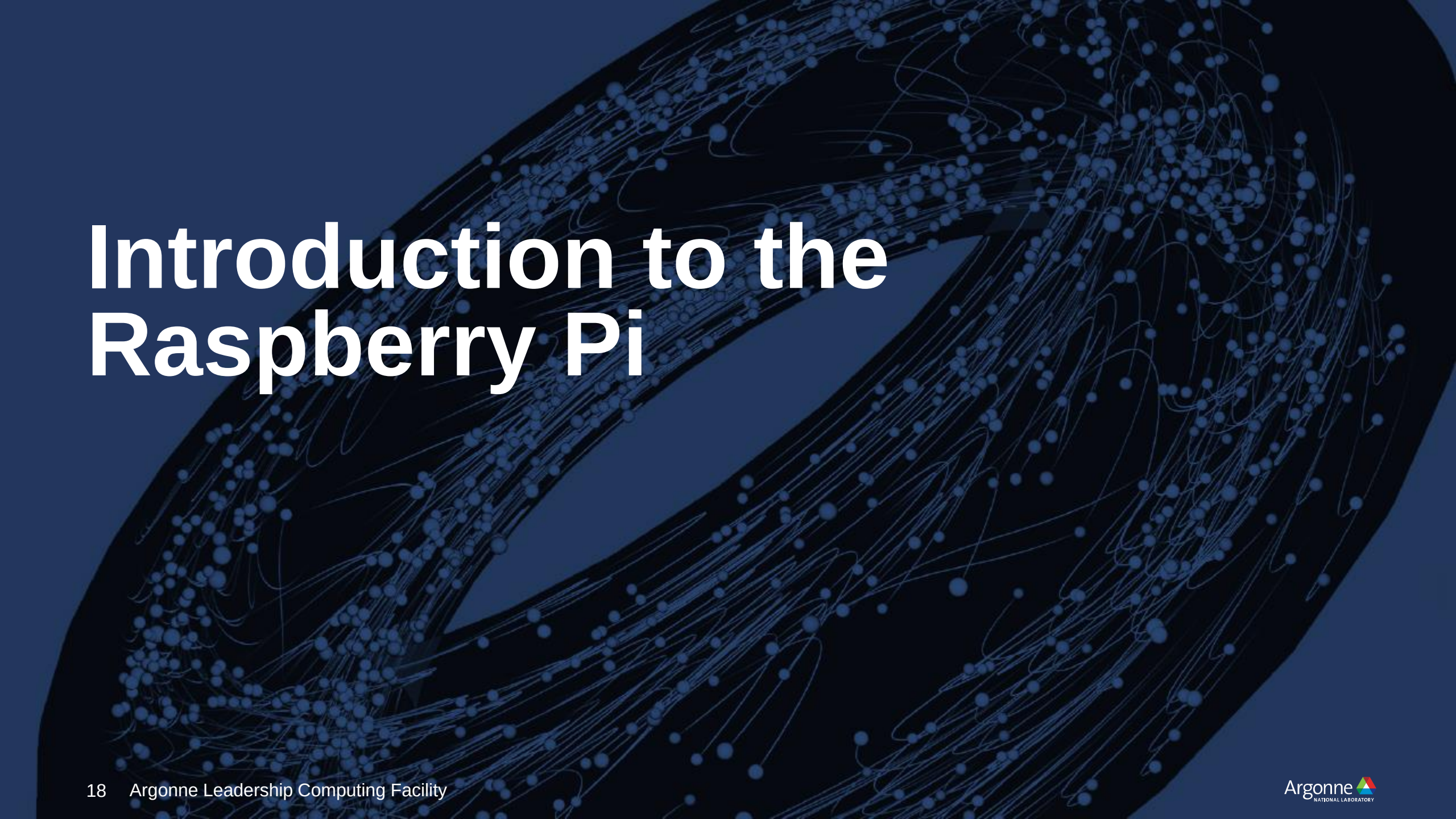
  - https://beagleboard.org/bone
- **PINE64**
  - https://www.pine64.org
- **Raspberry Pi**
  - https://www.raspberrypi.org

What’s the difference?

- **BeagleBone, PINE64, & Raspberry Pi**
  - Full fledged computers
  - Run an OS
  - Programmed with many different languages
  - More general purpose
  - More easily use networks
  - Large amount of RAM
- **Arduino**
  - Microcontroller
  - No OS, what you “flash” on it is the only thing that runs
  - Great for “real time” applications
  - Low power & can be tiny
- **All have General Purpose I/O (GPIO)**
  - Sensors, motors, relays

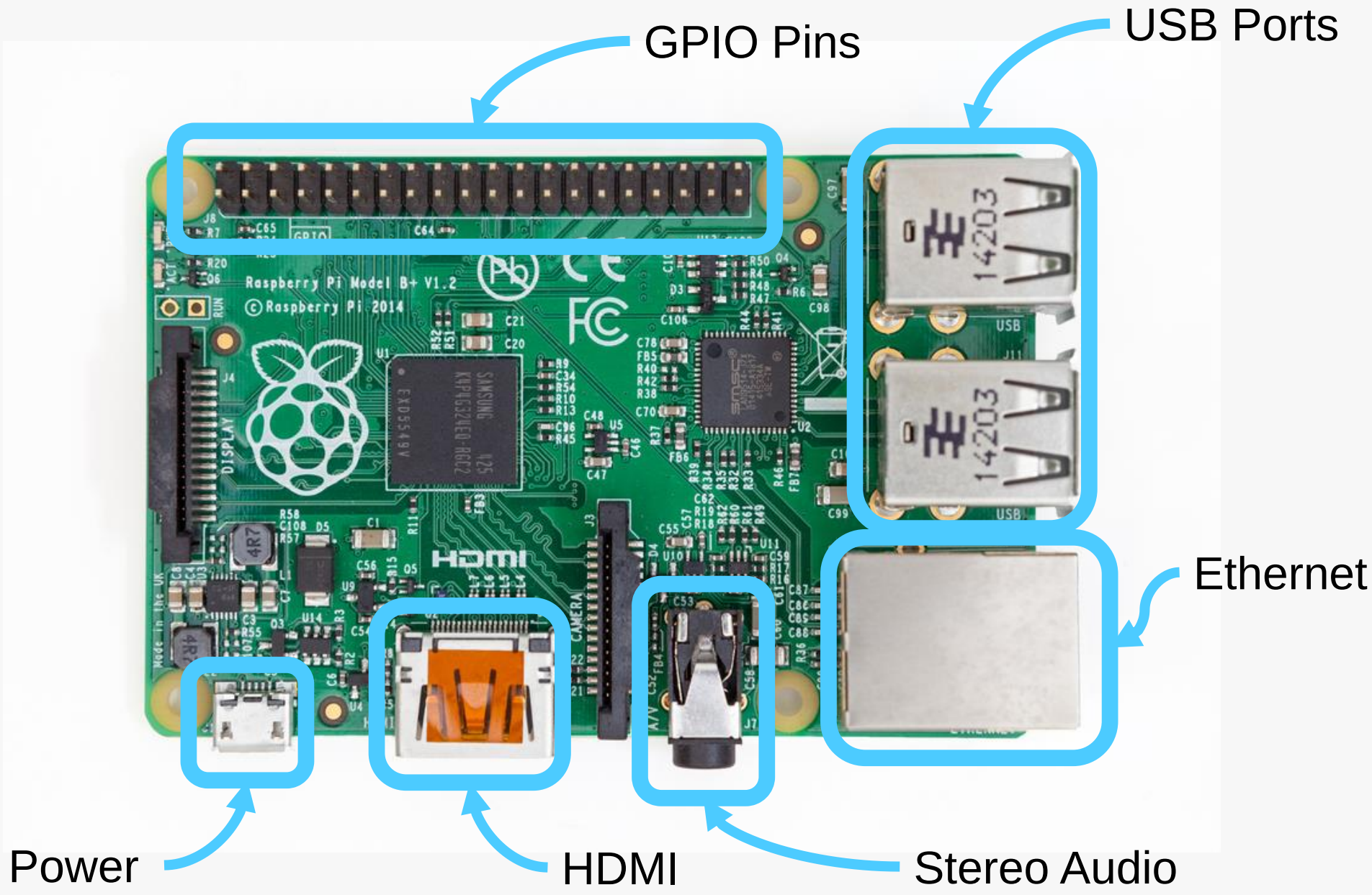
Why the Raspberry Pi?

- **It's cheap: $35**
- **Works with common components**
  - TV, keyboard, mouse, wireless, Bluetooth
- **Updated versions regularly**
  - Faster, more RAM, better I/O, etc.
- **Flexible**
  - Runs Windows & Linux
- **Huge user community**
  - Many existing projects and examples
- **MagPi**
  - Free to download monthly magazine
- **Lots of accessories**
  - Cameras, LCDs, sensors, cases



Introduction to the Raspberry Pi

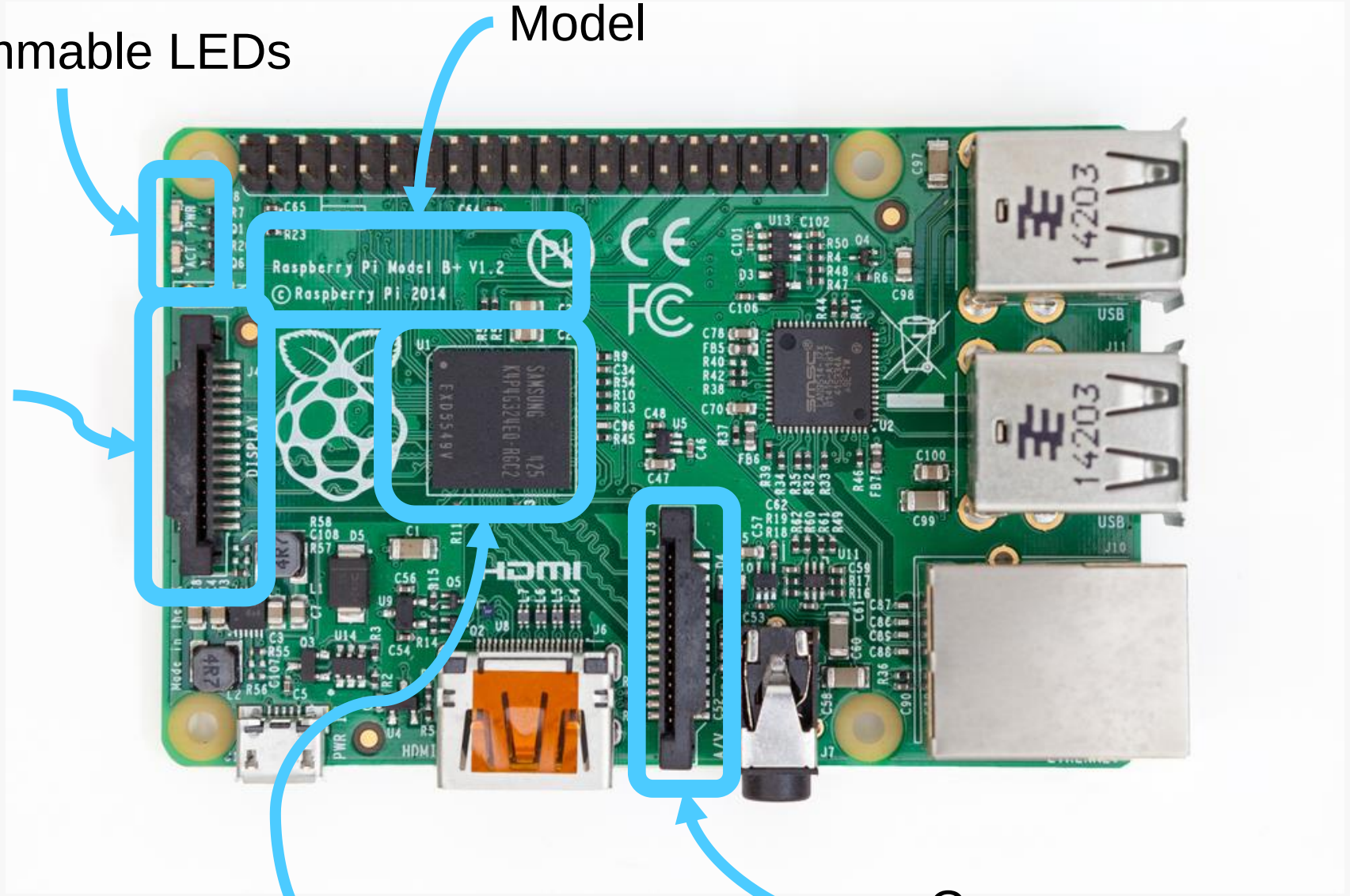

Raspberry Pi Model B+ V1.2
© Raspberry Pi 2014
GPIO
DISPLAY
HDMI
15262
15262


GPIO Pins
USB Ports
Ethernet
Micro USB Power
HDMI
Stereo Audio

Programmable LEDs

Model

External Display Connector



Processor & GPU

Camera Connector

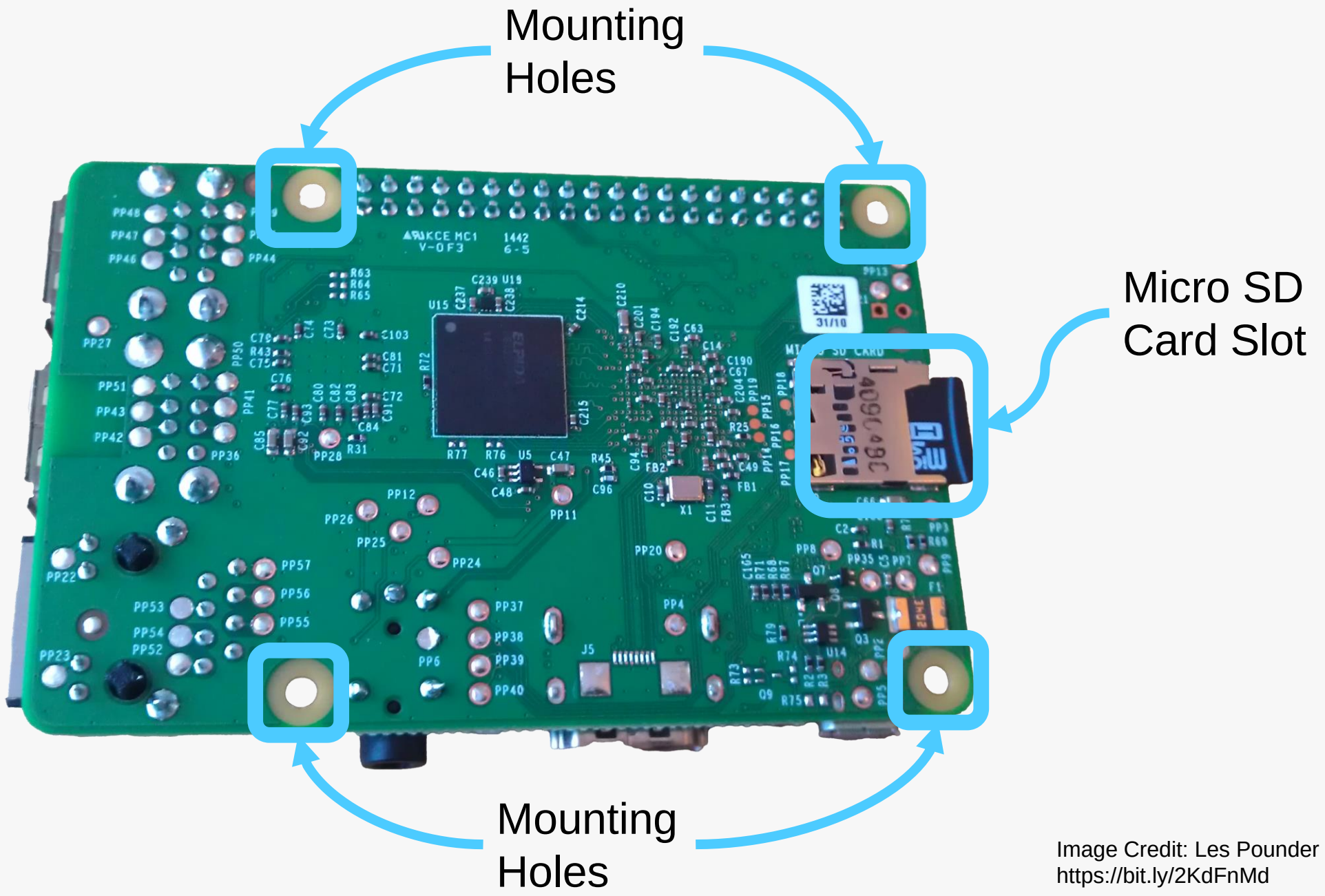
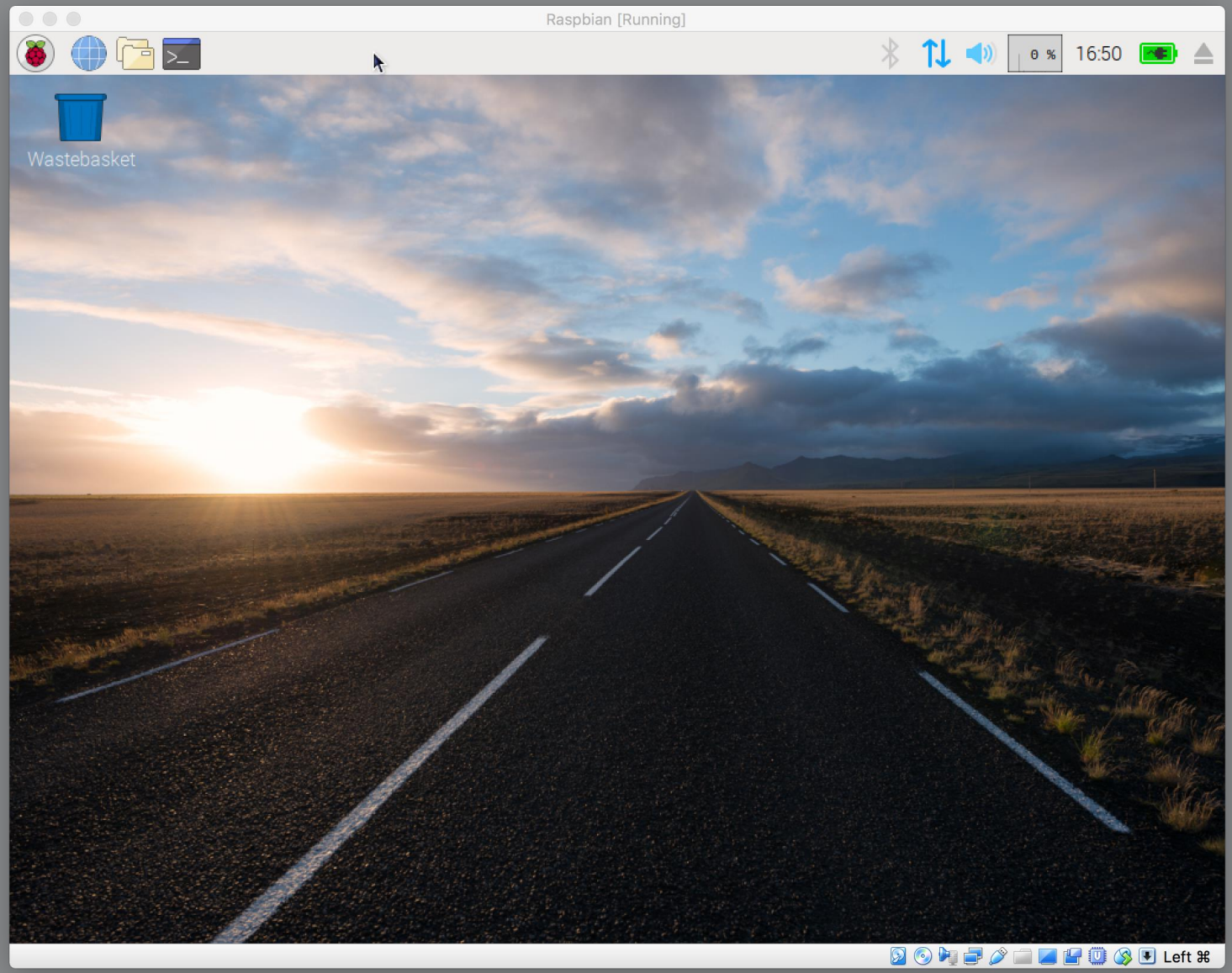


Image Credit: Les Pounder
https://bit.ly/2KdFnMd

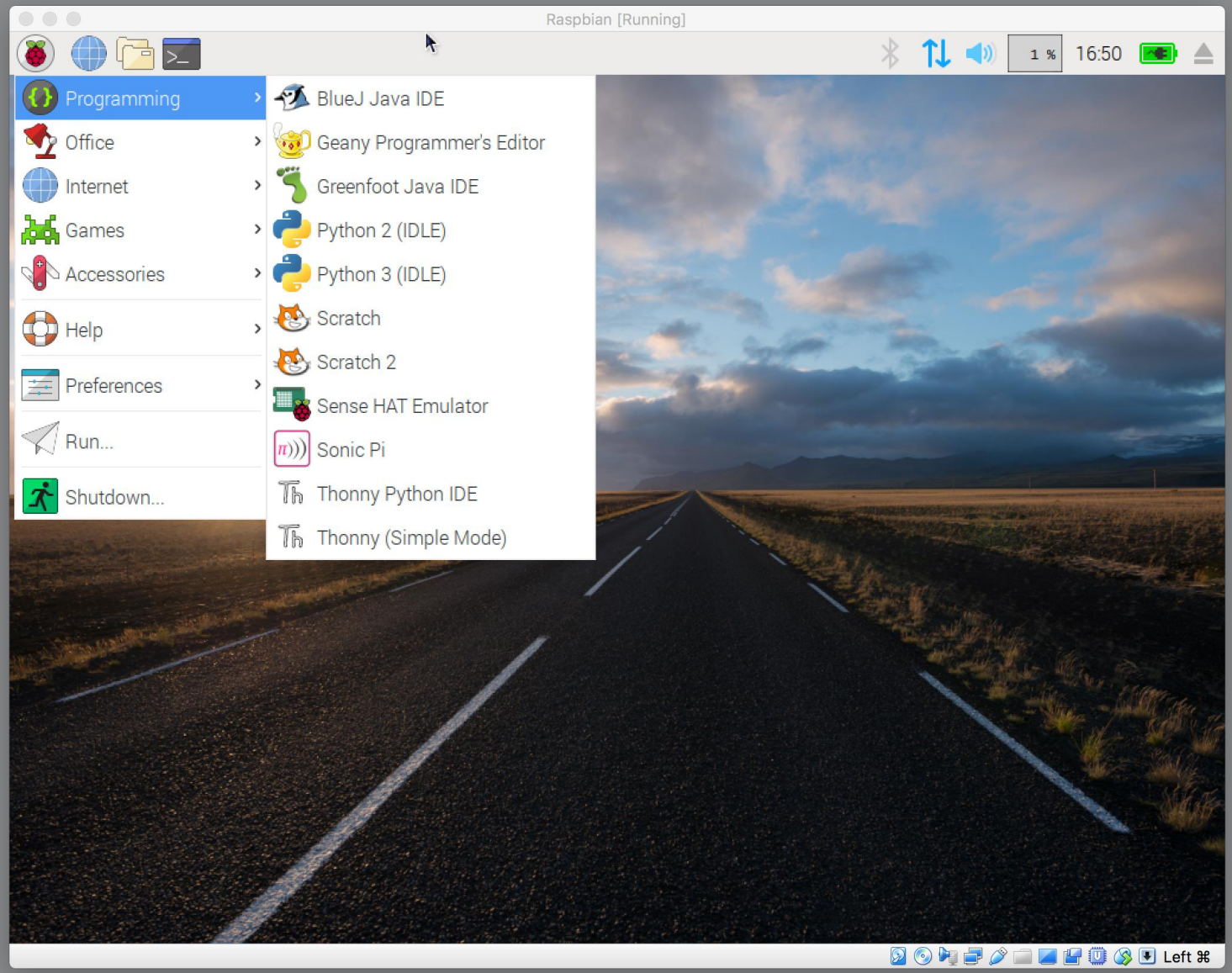
What do you need to get started?

- **HDMI monitor or TV**
- **HDMI cable**
- **USB keyboard and mouse**
- **8GB+ micro SD card**
- **SD card reader (your laptop may have one built in)**
- **OS image**
  - Raspbian: https://www.raspberrypi.org/downloads/raspbian/
- **Software to write to the SD card**
  - https://etcher.io/
- **Micro USB power adapter**
  - Many cell phone chargers will work
  - Make sure it is at least rated for 2.5A output
  - If in doubt, buy a UL rated one for a Raspberry Pi 3

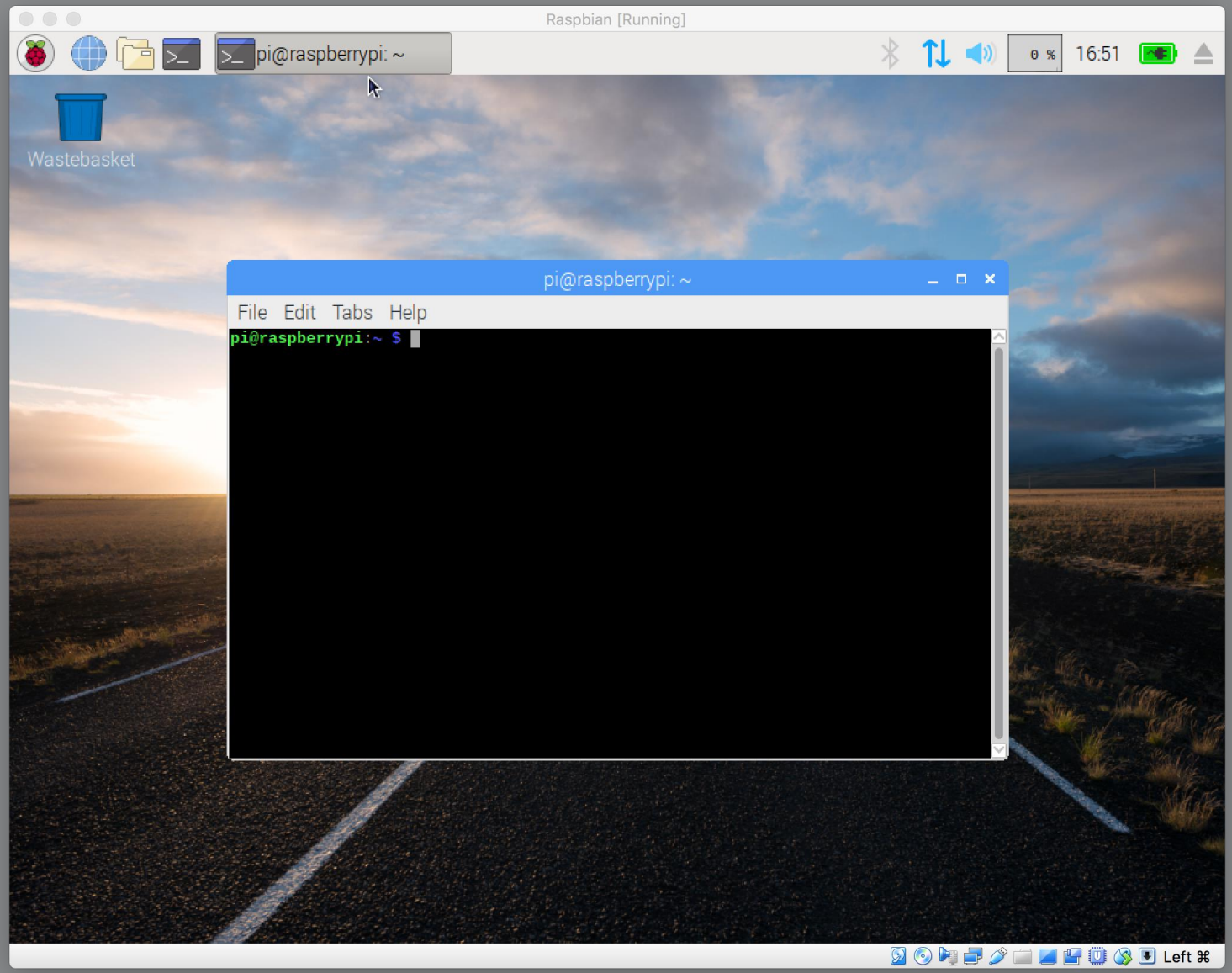
Raspbian OS - Desktop



Raspbian OS – Programming Menu



Raspbian OS – Terminal



Terminal is command line interface (CLI) to Linux

Let's you give OS commands via text

Many documents prepend CLI commands with a '$':

```
$ ls
```

`ls` is the command to list the files in the current directory

Useful Linux CLI commands

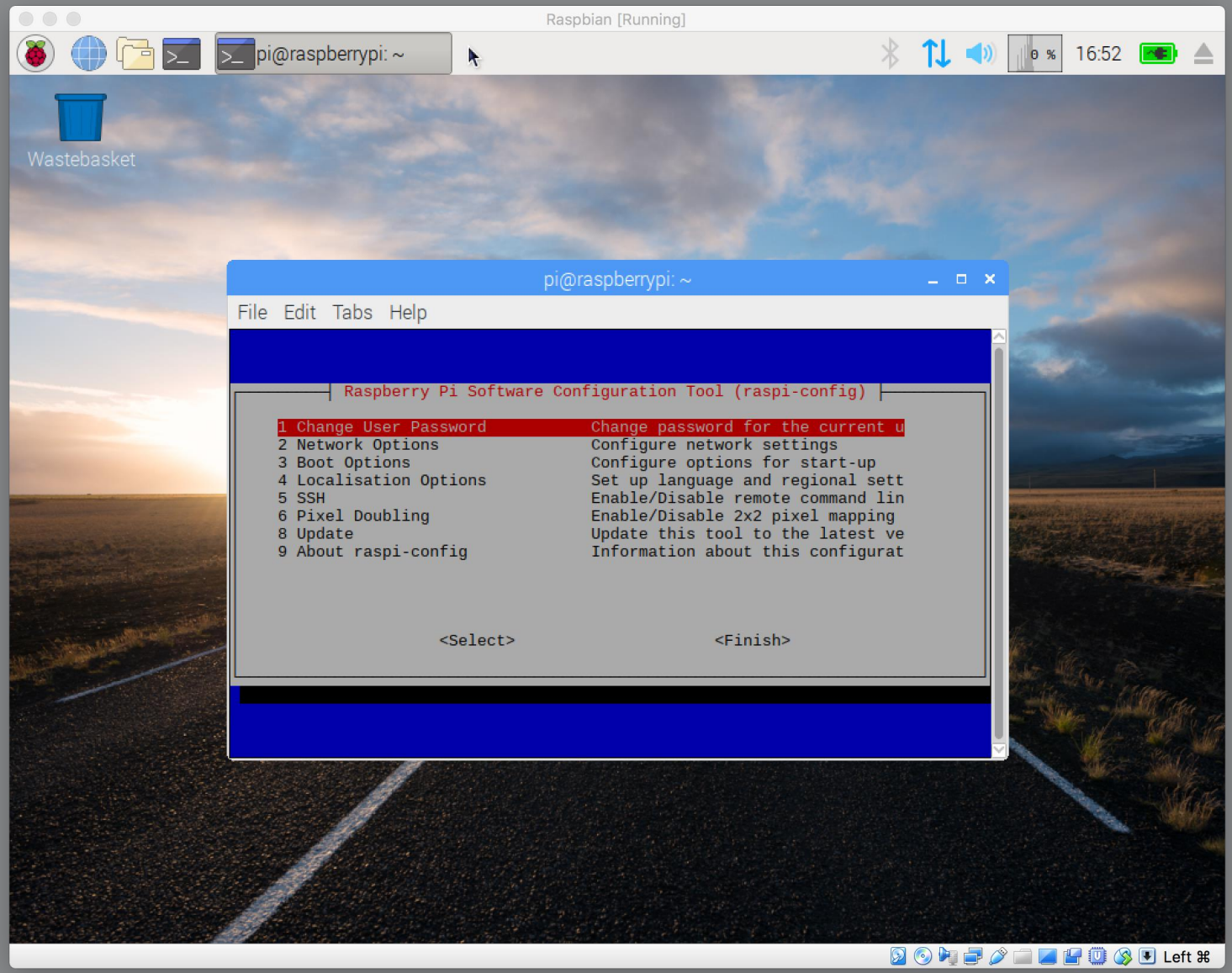
- `ls` : List files in the current directory
- `cd` : Change to a new directory
- `mv` : Move/rename a file
- `rm` : Remove/delete a file
- `man` : Read manual pages about commands
- `nano` : CLI text editor
- `sudo` : Run commands with elevated privileges (run as root)

- **Commands, their options, and their arguments are *case sensitive***

Linux Software

- There is a lot of freely available Linux software
- Many of the popular software packages are available in Raspbian
- `apt-cache` : Search for packages
  - `$ apt-cache search apt-file`
- `apt-get` : Install, update, delete packages
  - `$ sudo apt-get install apt-file`
  - `$ sudo apt-get update`
  - `$ sudo apt-get upgrade`
- `apt-file` : Find what package provides a file
  - `$ apt-file search pip`
- `dpkg` : Show information about packages
  - `$ dpkg -l`
  - `$ dpkg -L python-pip`

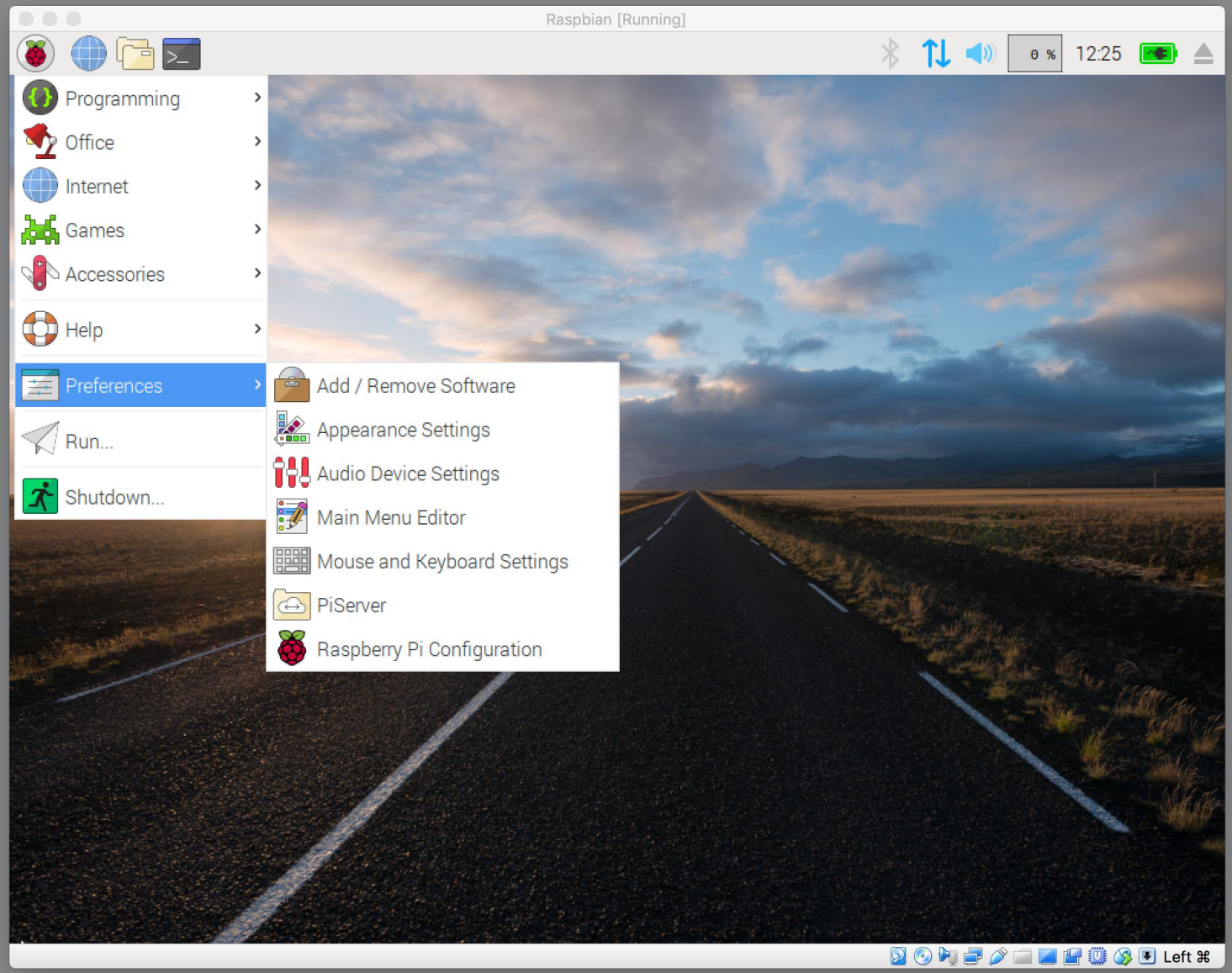
Raspbian OS – raspi-config



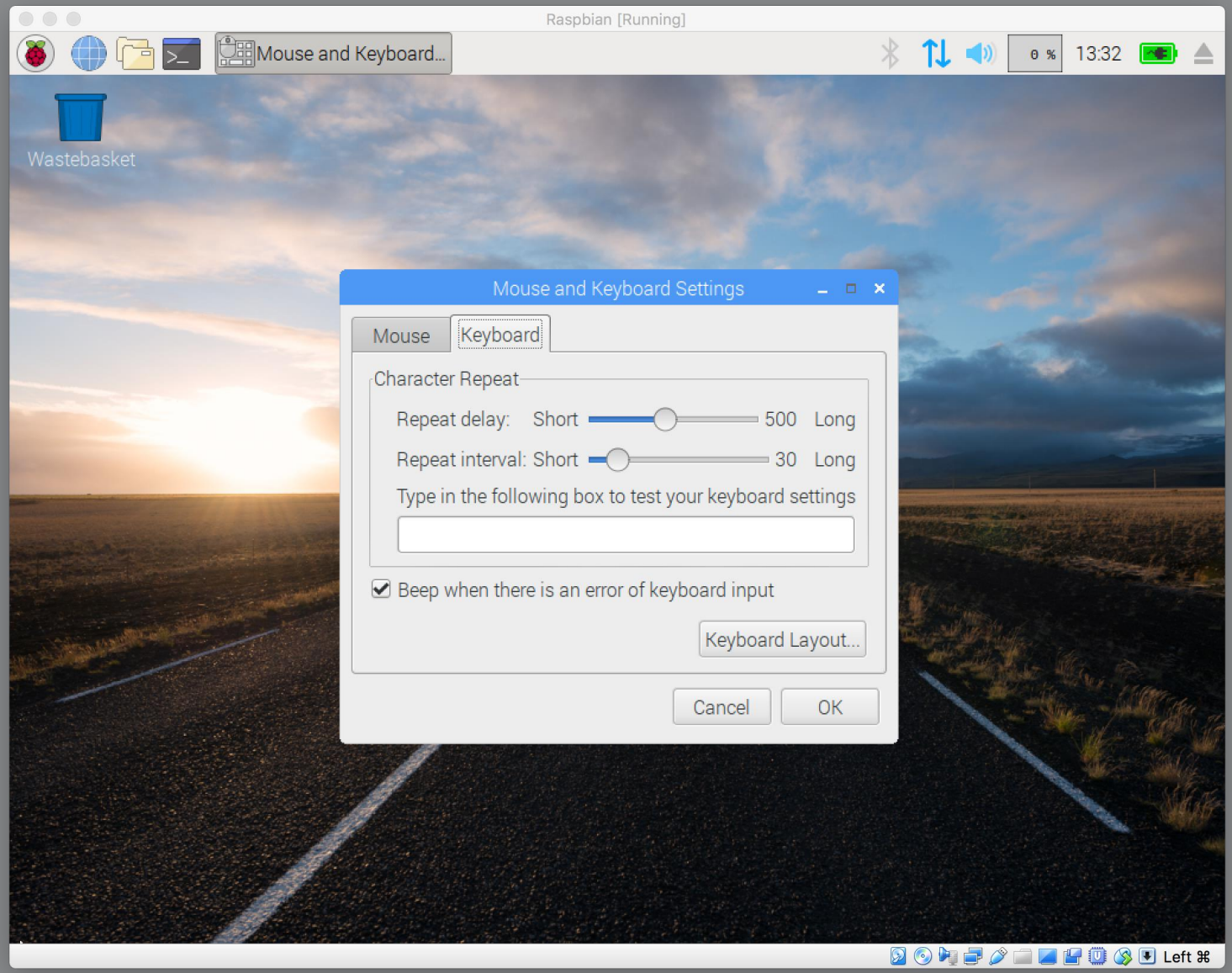

```
$ sudo raspi-config
```

Change the Locale under Localisation Options from `en.GB.UTF-8 UTF-8` to `en.US.UTF-8 UTF-8`

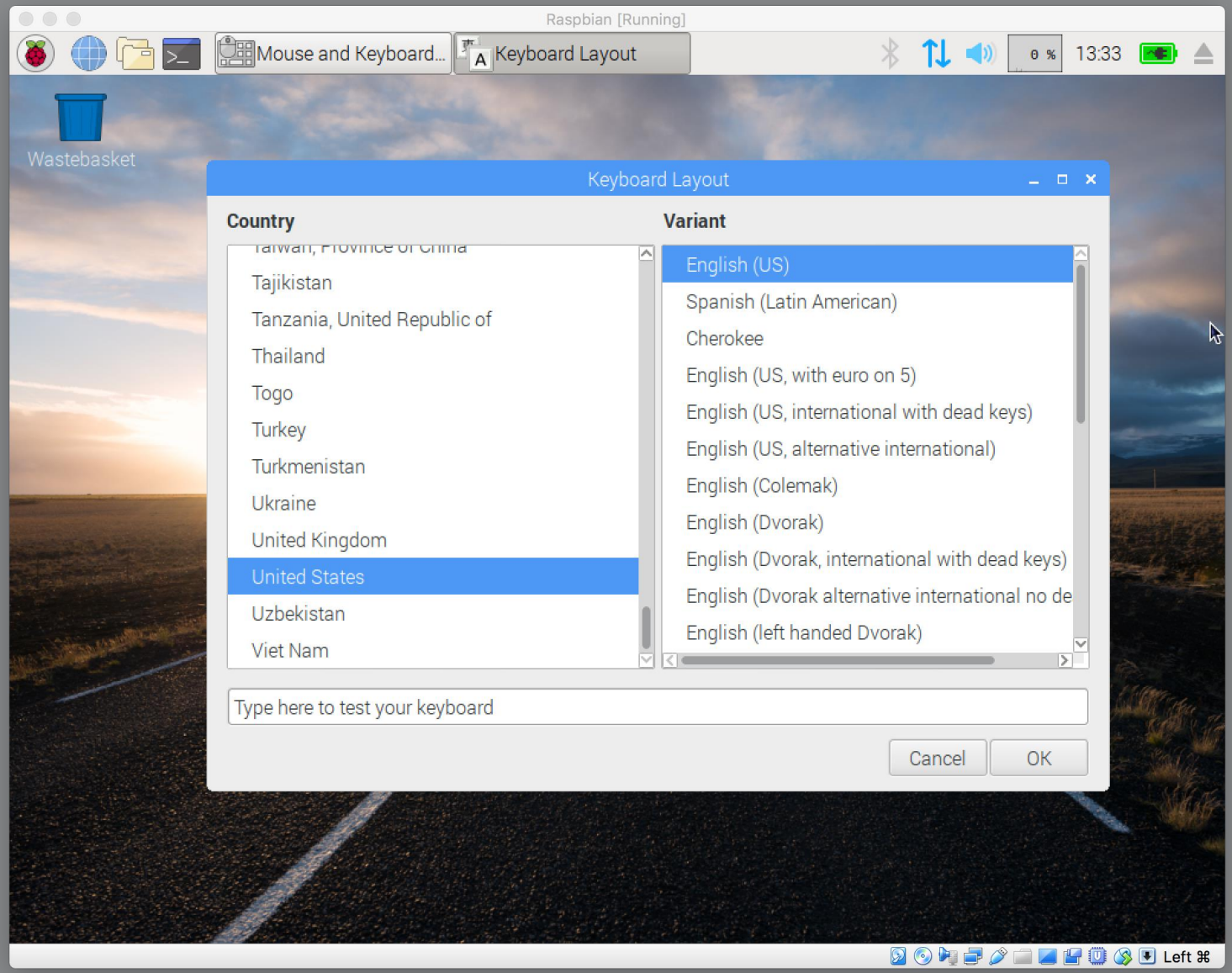
Raspbian OS – Update Keyboard Layout



Raspbian OS – Update Keyboard Layout



Raspbian OS – Update Keyboard Layout



Programming 101

What is a computer?

A computer is a general purpose device that can be ***programmed*** to carry out a set of ***arithmetic*** or ***logical*** operations automatically.

Computers have:

- **Input**
- **Output**
- **Storage**
- **Processing**

What is a program?

A recipe of arithmetic and logical operations in specific order.

This recipe is called an ***algorithm***.

We'll explore arithmetic and logical operations later.

Scrambled Eggs:

Mixture = 2 eggs + salt + pepper

IF Mixture is hot AND mixture is cooked THEN eat

Human langauges

- Let's write "Good Morning!" in 3 different languages: English, Spanish, Japanese
- English: Good Morning!
- Spanish: ¡Buenos Días!
- Japanese: おはよう!

Why computer languages?

- **International scientists communicate with each other in English**
- **Similarly, if we want computers to understand what we want them to do, we must write our programs using a *computer language***
- **A *computer language* allows humans to communicate with computers in a meaningful way**

Many computer languages

- Just like there are many *human languages*, there are many *computer languages* as well
- Let's write a *"Hello, world!"* program in 4 different languages: Pseudo code, C, Python, JavaScript

Pseudo Code

```
Display “Hello, world!”
```

C

```
#include <stdio.h>
int main() {
     printf(“Hello, world!”);
     return(0);
}
```

Javascript

```
document.write(“Hello, world!”);
```

Python

```
print(“Hello, world!”)
```

An example Python program

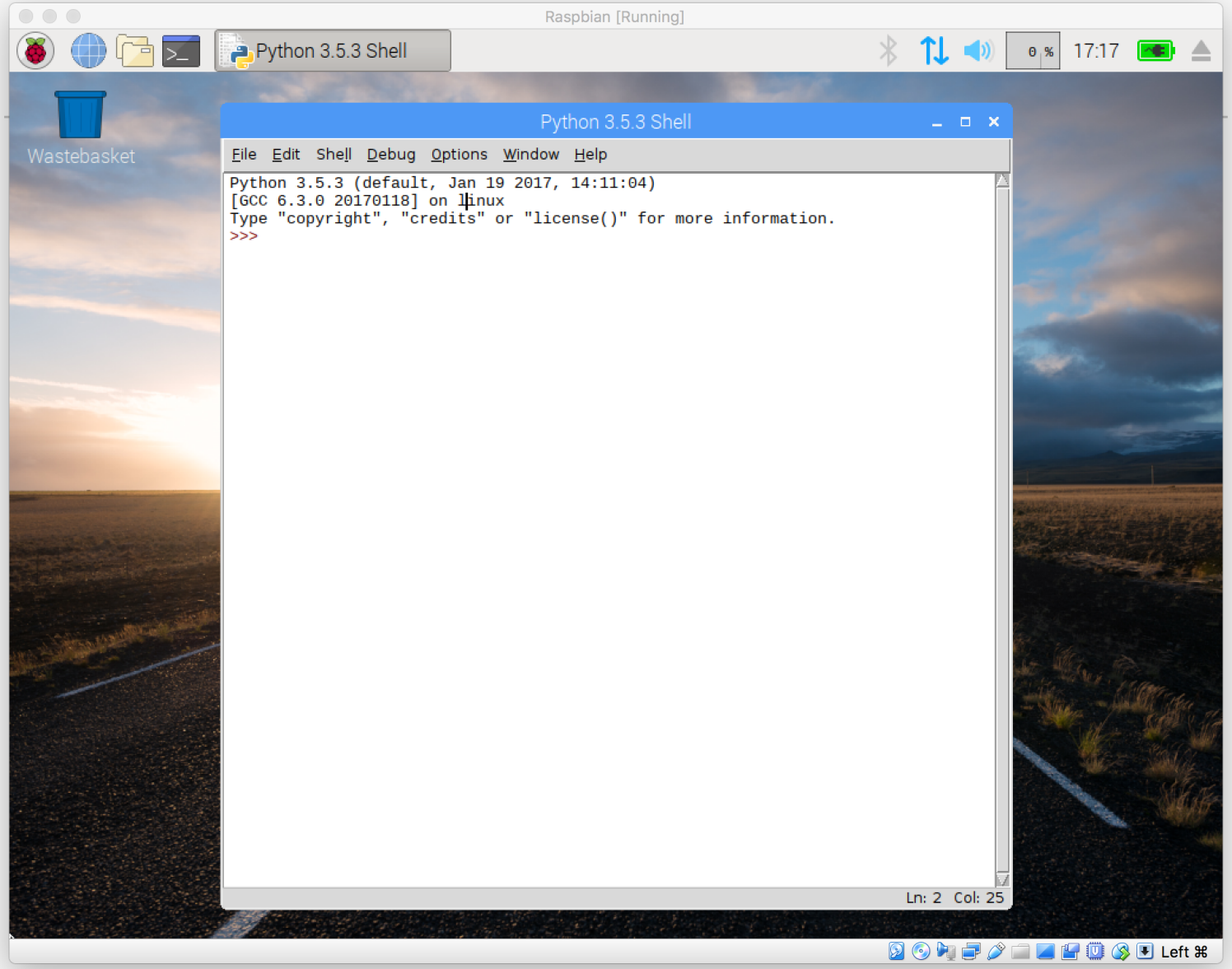
```
import random
num = random.randint(1, 100)

while True:
    print('Guess a number between 1 and 100')
    guess = input()
    i = int(guess)
    if i == num:
        print('You guessed right')
        break
    elif i < num:
        print('Try higher')
    elif i > num:
        print('Try lower')
```

Let’s talk to the computer

Open IDLE for Python 3 and write a “Hello, world!” program.

Let’s talk to the computer



Python *shell*

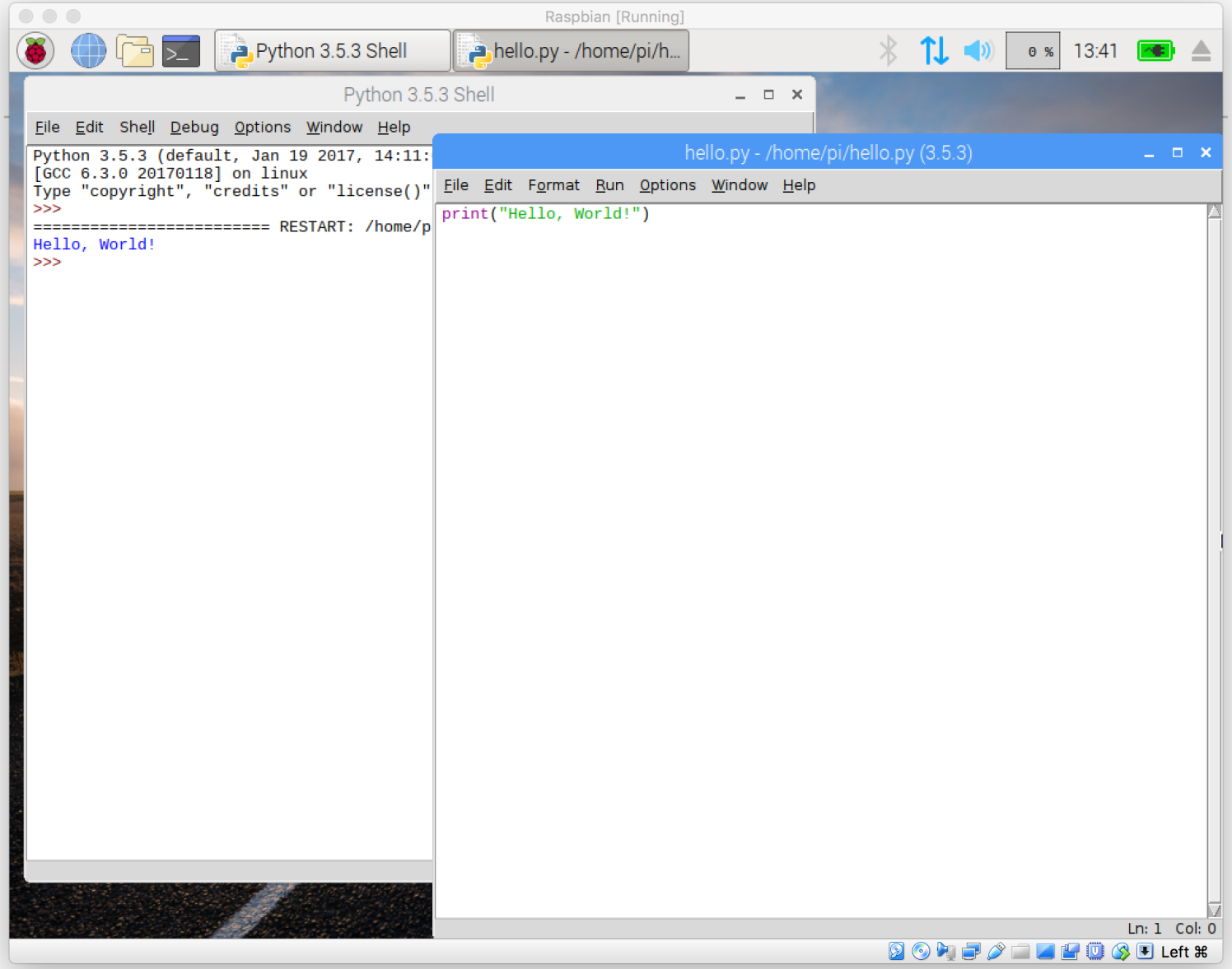
Prompt: >>>

Let’s talk to the computer

- Make sure to include double quotes
- Press enter when done

```
>>> print(”Hello, World!”)
Hello, World!
>>>
```

Let’s talk to the computer



1. From Menu:
   `File -> New File`
2. Type in the previous code
3. **`File -> Save`**
   Name it **`hello.py`**
4. **`Run -> Run module`**

Binary

- On/Off, High/Low, Open/Closed, True/False, 1/0
- True/False values also referred to as Booleans
- Everyone knows how to count to 12 in decimal

- Let’s count to 12 in binary

Why Python?

- Python is a language that was designed to be easy to read and use fewer symbols (!#$*)

Python

```
print("Hello, World!")
```

C++

```
int main()
{
  std::cout << "Hello, world!" << std::endl;
  return(0);
}
```

English Grammar

- Let’s eat Grandma!

  vs.

- Let’s eat, Grandma!

- In english how do you end a question.

Programming Language Syntax

- Just like grammar, it helps you read a sentence.
- Language has a syntax that lets the computer read your program.
- If you get the syntax wrong, the computer will have an error running your program
- Python is case sensitive.

Working with data in Python

Arithmetic Operators

- `+, -, *, /, (, )`
  - `1+1`
  - `1+2*4`
  - `(1+2)*4`
  - `1+!`
  - `2/0`

Order of operations

- Computers do exactly what you tell them in the order you tell them.
- Be explicit.

Logical Operators

- `>, <, >=, <=, ==, !=`
  - `2>1`
  - `2>4`
  - `2>=2`
  - `2==2`
  - `2==1`
  - `2!=1`

Booleans

- Just like arithmetic operators manipulate numbers, logical operators manipulate Booleans.
- Logical operations return a Boolean for the answer, instead of a number

Logical Operators

- `and, or, not`
  - `True and True`
  - `True and False`
  - `True or False`
  - `not True`
  - `2<4 and 1<=2`

Booleans

- Just like arithmetic operators manipulate numbers, logical operators manipulate Booleans.
- Logical operations return a Boolean for the answer, instead of a number

Variables

- Variables are like containers
- Examples

```
>>> fred = 100
>>> print(fred)
100
```

Variable Names

- Letters
- Numbers
- _ (underscore)

Using Variables

- Let’s try the following code

```
>>> found_coins = 20
>>> magic_coins = 10
>>> print(found_coins)
```

- What should be the output value?
- Let’s now add the following line. What would be the output?

```
>>> print(found_coins + magic_coins)
```

What are Data Types?

Examples:

- **String:** “I am 1 string”, “What’s up?”, “cheese”
- **Integer:** 10, -42, 12000, 9
- **Float:** 3.2, 0.00001, -10900.999, 123.456
- **Boolean:** True, False

What are Data Types?
(and why are they important?)

- Remember when we talked about binary?
- Computer only understands 0 and 1
- We need to tell it how to interpret them

Example

- 30 : `11110`
- “30” : `00110011 00110000`

Controlling program flow

Counting Numbers

Let’s count natural numbers:

- 1 2 3 4 5 6 ....

Now let’s try using Python sentences:

```
print(1)
print(2)
print(3)
print(4)
...
```

and so on

Counting Numbers with a Loop

There is a common construct in almost all computer languages called *for loop*

```
for x in range(1, 6):
    print(x)
```

Result:

```
1
2
3
4
5
```

Making Choices with Conditionals

- Remember logical operators?
  - `>, <, >=, <=, ==, !=`
- Use these to make comparisons:

```
if (some condition is True):
    do something
    do another thing
else:
    do something different
    do more stuff
```

Checking Numbers

Let's combine loops and conditionals

```
for x in range(1, 7):
    if (x<3):
        print("Not close")
    elif (x<=5)
        print("Almost there")
    else:
        print(x)
```

Result:

```
Not close
Not close
Almost there
Almost there
Almost there
6
```

Code Reuse

Let’s Recycle (Programmer’s are lazy)

- Reuse common code
  - Only need to figure out how to do something once
  - Don’t have to type the same code over and over
  - Makes your code cleaner and shorter (easier to read)
  - Reduces errors
- Multiple ways in Python (and other languages)
  - Functions
  - Modules or Libraries

Functions and Modules

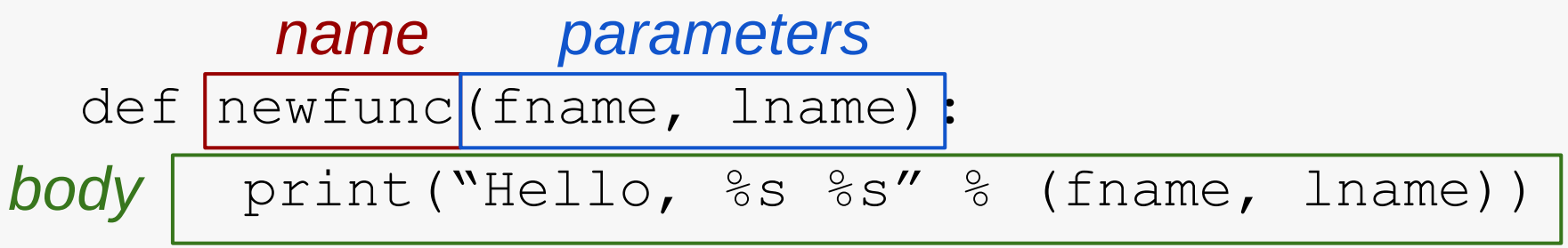
- **Functions** are like tools that you can use again and again

- **Modules** are like toolboxes, used to hold related tools

Functions

- We used them a bunch already
  - `print()`
  - `range()`

Defining a New Function



Functions

- A function is often used to return a value, using a return statement. For example, you could write a function to calculate how much money you were saving:

```
def savings(pocket_money, paper_route, spending):
        return pocket_money + paper_route - spending

print( savings(10, 10, 5) )
```

Result:

```
15
```

Variables and Scope

Scope:

Scope determines when a variable is “visible” or valid

```
def variable_test():
    first_variable = 10
    second_variable = 20
    return first_variable * second_variable
print(first_variable)

NameError: name 'first_var' is not defined
```

Why?

The variable `first_variable` is only defined within the scope of the function `variable_test()`. It does not exist outside the function.

Different Scopes

- If a variable is defined outside the function, it has a different *scope*

```
another_variable = 100
def variable_test():
    first_variable = 10
    second_variable = 20
    return first_variable * second_variable

print(variable_test())
print(another_variable)
print(first_variable)
```

Result:

```
200

100

NameError: name
'first_variable' is not
defined
```

Python Modules

- Just like Linux software there are a lot of available Python modules
- Many of the popular Python modules are available in Raspbian
  - NumPy : `$ apt-get install python3-numpy`
  - SciPy : `$ apt-get install python3-scipy`
  - pigpio : `$ apt-get install python3-pigpio`

- Discover what modules are available in Python

```
>>> help()
help> modules
```

- Use Python Packaging Index (PyPI) - https://pypi.org/
  - `pip search numpy`
  - `pip install numpy`

Using Modules

- Use the `import` directive

```
import datetime as dt

print(dt.date.today())
```

Result:

```
2018-04-29
```

Specific Importing

- Use the `from` directive

```
from datetime import date

print(date.today())
```

Result:

```
2018-04-29
```

Data Structures

Argonne NATIONAL LABORATORY

Lists
Also Called Arrays

- Create a list of strings
  - Declare using `[]`

```
>>> food=['hotdog buns', 'coffee', 'eggs',
'orange juice']
>>> print (food[1])
```

- List index starts at 0

- Change value of entry

```
>>> food[3]='milk'
>>> print(food)
```

Result:

```
coffee


['hotdog buns', 'coffee',
'eggs', 'milk']
```

Lists of Lists
Also Called Multi-dimensional Arrays

```
>>> numbers=[12, 74, 8, 506]
>>> mixed_list=['We', 'have', 2, 'wait', 4, 'dinner']
>>> mylist=[mixed_list, numbers]
>>> print(mylist)
```

Result:

```
[['We', 'have', 2,
'wait', 4, 'dinner'],
[12, 74, 8, 506]]
```

Tuples

- Like lists but declare with `()` instead of `[]`

```
>>> lakes=('Huron', 'Ontario', 'Michigan',
'Erie', 'Superior')
>>> lakes[1]
```

- Cannot change values once declared

```
>>> lakes.append('Crystal')
>>> lakes[1]='Crystal'
```

Result:

```
'Ontario'

AttributeError: 'tuple'
object has no attribute
'append'

TypeError: 'tuple' object
does not support item
assignment
```

Maps
Also called Dicts or Dictionaries

- Collection of things, similar to lists and tuples
- Key : Value pairs instead of index

```
>>> bdays={‘Jim’ : ‘May 4’, ‘Sue’ : ‘April 20’,
‘Ed’ : ‘July 17’}
>>> print(bdays[‘Sue’])
>>> bdays.update({‘Sam’: ‘Dec 8’})
>>> print(bdays)
>>> del bdays[‘Ed’]
>>> bdays[‘Sam’] = ‘dec 10’
>>> print(bdays)
```

Result:

```
April 20

{'Jim': 'May 4', 'Sue':
'April 20', 'Ed': 'July
17', 'Sam': 'Dec 8'}

{'Jim': 'May 4', 'Sue':
'April 20', 'Sam': 'Dec
10'}
```

Indexing and Slicing Strings
Hint: Strings are Lists of Characters

```
>>> fred="Hello, Fred"
>>> print (fred[4])
```

- Index starts at 0

```
>>> print (fred[2:8])
```

- From index 2 up to, but not including, index 8

```
>>> print(fred[8:])
>>> print(fred[:5])
```

Result:

```
o

llo, F

red

Hello
```

Loops with Lists

```
wizard_list = ['spider legs', 'toe of frog',
'snail tongue’,'bat wing', 'slug butter', 'bear
burp’]
for i in wizard_list:
      print(i)
```

“For each item in `wizard_list`, store the value in the variable `i`, and then print the contents of that variable”

Result:

```
spider legs
toe of frog
snail tongue
bat wing
slug butter
bear burp
```

Working with a Team

Mojang (Minecraft)

- Markus “Notch” Persson
- Has anyone heard of Minecraft?
- Worth over $1.3 Billion

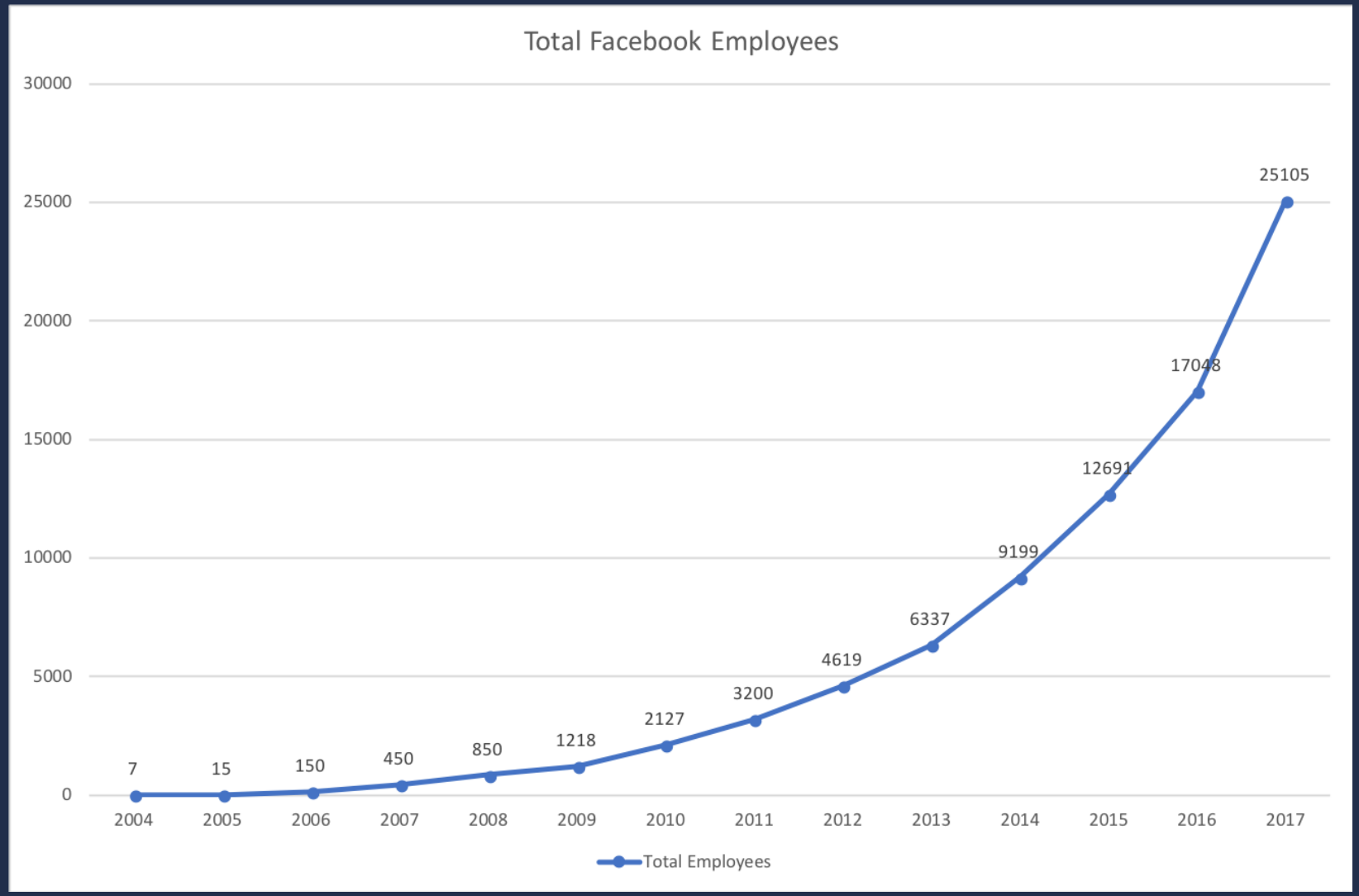
Mojang Jobs

- Developer
- Artist
- Architect
- Designer
- Project Manager
- Customer Support
- DevOps Engineer

Facebook

- Mark Zuckerberg, CEO
- Worth $66.4 Billion

Facebook Employees



Data Credit: Statista
https://bit.ly/2Kn8FrW

Teams

- So what do all these people do?
- Why can’t just one person do everything?
- So how do you work on a team?
  - Agree to and document standards
  - Version Control – git, svn, mercurial, etc.
  - Comment your code
  - Communicate

https://github.com/

https://git-scm.com/doc

Debugging

- You *will* make mistakes
- Your team *will* make mistakes
- Finding and fixing problems in your program
- As simple as adding `print` statements
- As sophisticated as an interactive debugger like `pdb`
- Effective debugging is as much an art form as a skill

Performance

- There is almost always more than one way to solve a problem
- Some ways are better in certain situations than others and worse in other situations
- You might have a *correct* algorithm that isn't the *right* algorithm for the job
  - http://www.sorting-algorithms.com/

Questions

Acknowledgement

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