

THE OFFICIAL
Raspberry Pi
Beginner's Guide
How to use your new computer



First published in 2019 by Raspberry Pi Trading Ltd, Maurice Wilkes Building,
St. John's Innovation Park, Cowley Road, Cambridge, CB4 0DS

Publishing Director: Russell Barnes • Editor: Phil King • Sub Editor: Nicola King
Design: Critical Media • Illustrations: Sam Alder
CEO: Eben Upton

ISBN: 978-1-912047-62-8

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Welcome to the Official Raspberry Pi Beginner's Guide

We think you're going to love the Raspberry Pi. This ultra-small, affordable computer costs less than most video games, but can be used to learn coding, build robots, and create all kinds of weird and wonderful projects.

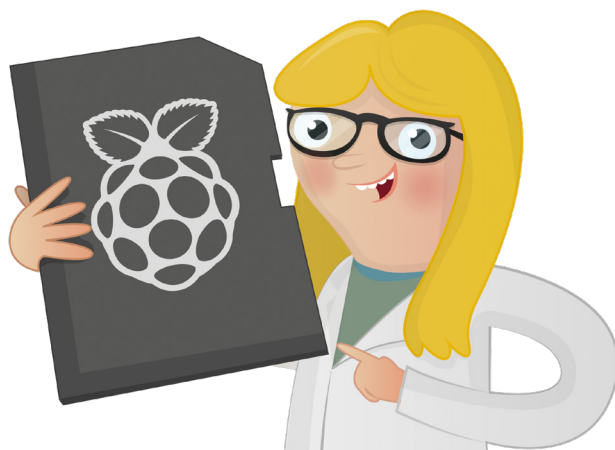
The Raspberry Pi is capable of doing all the things you'd expect from a computer – everything from browsing the internet and playing games, to watching movies and listening to music. But the Raspberry Pi is much more than a modern computer.

With a Raspberry Pi you can get into the heart of a computer. You get to set up your own operating system, and can connect wires and circuits directly to the pins on its board. It was designed to teach young people how to program in languages like Scratch and Python, and all the major programming languages are included with the official operating system.

The world needs programmers more than ever, and the Raspberry Pi has ignited a love of computer science and technology in a new generation.

People of all ages use the Raspberry Pi to create exciting projects: everything from retro games consoles to internet-connected weather stations.

So if you want to make games, build robots, or hack a variety of amazing projects, then this book is here to help you get started.



About the Author

Gareth Halfacree is a freelance technology journalist, writer, and former system administrator in the education sector. With a passion for open-source software and hardware, he was an early adopter of the Raspberry Pi platform and has written several publications on its capabilities and flexibility. He can be found on Twitter as **@ghalfacree** or via his website at **freelance.halfacree.co.uk**.



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Chapter 1

Get to know your Raspberry Pi

Get fully acquainted with your new credit-card-sized computer by taking a guided tour of the Raspberry Pi. Discover its numerous components and what they do



The Raspberry Pi is a remarkable device: a fully functional computer in a tiny and low-cost package. Whether you're looking for a device you can use to browse the web or play games, are interested in learning how to write your own programs, or are looking to create your own circuits and physical devices, the Raspberry Pi – and its amazing community – will support you every step of the way.

The Raspberry Pi is known as a *single-board computer*, which means exactly what it sounds like: it's a computer, just like a desktop, laptop, or smartphone, but built on a single *printed circuit board*. Like most single-board computers, the Raspberry Pi is small – roughly the same footprint as a credit card – but that doesn't mean it's not powerful: a Raspberry Pi can do anything a bigger and more power-hungry computer can do, though not necessarily as quickly.

The Raspberry Pi family was born from a desire to encourage more hands-on computer education around the world. Its creators, who joined together to form the non-profit Raspberry Pi Foundation, had little idea that it would prove so popular: the few thousand built in 2012 to test the waters were immediately sold out, and millions have been shipped all over the world in the years since. These boards have found their ways into homes, classrooms, offices, data centres, factories, and even self-piloting boats and spacefaring balloons.

Various models of Raspberry Pi have been released since the original Model B, each bringing either improved specifications or features specific to a particular use-case. The Raspberry Pi Zero family, for example, is a tiny version of the full-size Raspberry Pi which drops a few features – in particular the multiple USB ports and wired network port – in favour of a significantly smaller layout and reduced power requirements.

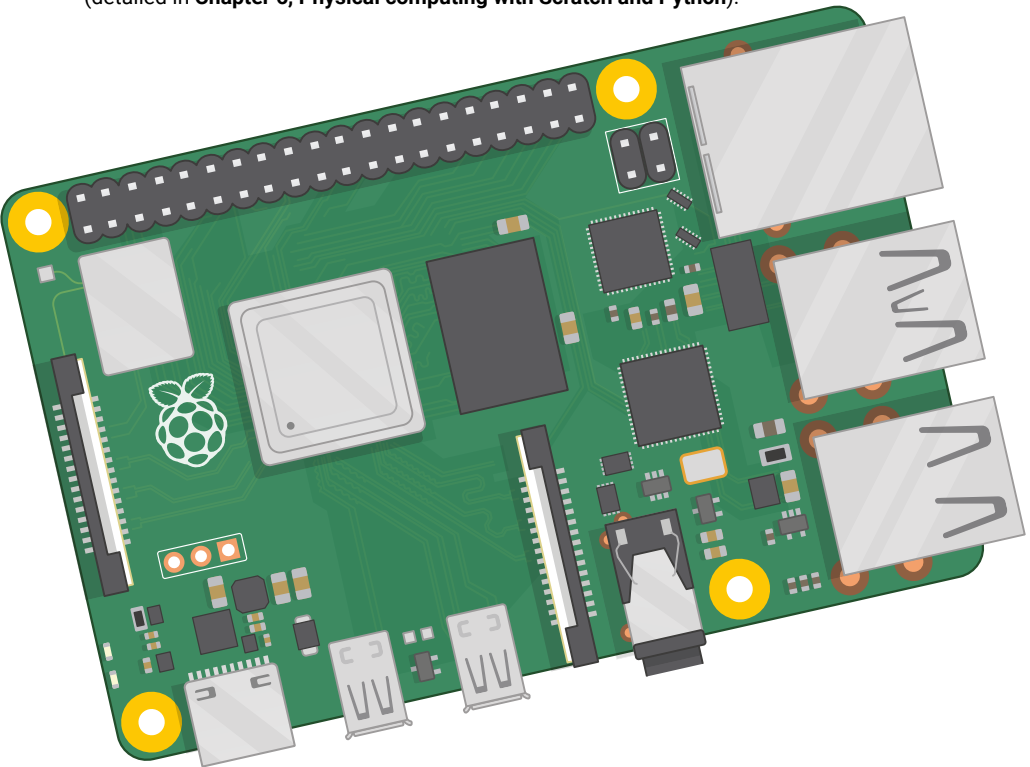
All Raspberry Pi models have one thing in common, though: they're *compatible*, meaning that software written for one model will run on any other model. It's even possible to take the very latest version of the Raspberry Pi's operating system and run it on an original pre-launch Model B prototype. It will run more slowly, it's true, but it will still run.

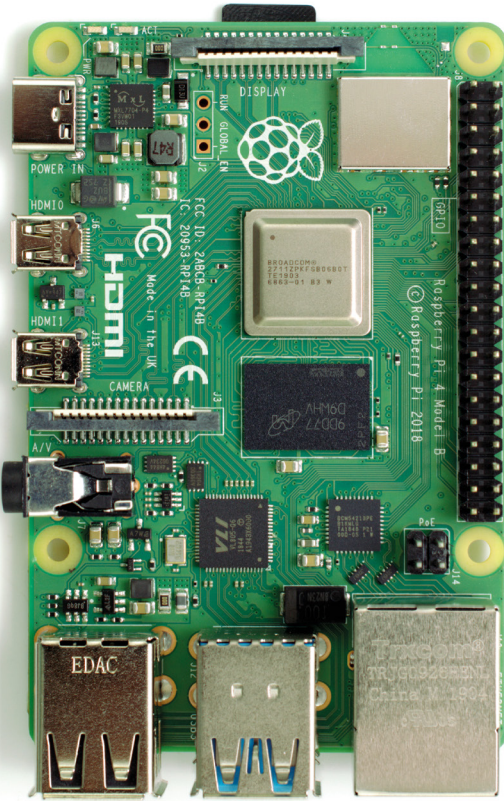
Throughout this book you'll be learning about the Raspberry Pi 4 Model B, the latest and most powerful version of the Raspberry Pi. What you learn, though, can be easily applied to other models in the Raspberry Pi family, so don't worry if you're using a different version.

A guided tour of the Raspberry Pi

Unlike a traditional computer, which hides its inner workings in a case, a Raspberry Pi has all its components, ports, and features out on display – although you can buy a case to provide extra protection, if you'd prefer. This makes it a great tool for learning about what the various parts of a computer do, and also makes it easy to learn what goes where when it comes time to plug in the various extras – known as *peripherals* – you'll need to get started.

Figure 1-1 (overleaf) shows the Raspberry Pi 4 Model B as seen from above. When you're using a Raspberry Pi with this book, try to keep it turned the same way as in the picture; if it's turned around it can get confusing when it comes to using things like the GPIO header (detailed in **Chapter 6, Physical computing with Scratch and Python**).



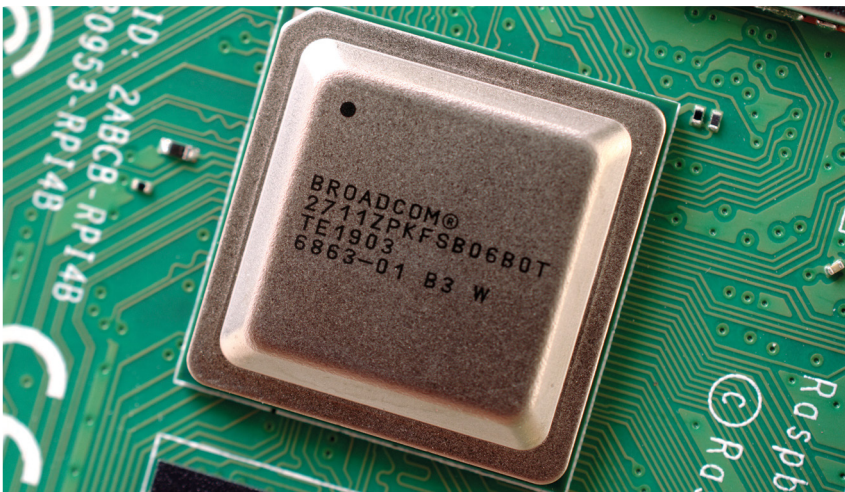


◀ **Figure 1-1: The Raspberry Pi 4 Model B**

While it may look like there's a lot packed into the tiny board, the Raspberry Pi is very simple to understand – starting with its *components*, the inner workings that make the device tick.

The Raspberry Pi's components

Like any computer, the Pi is made up of various different components, each of which has a role to play in making it work. The first, and arguably most important, of these can be found just above the centre point on the top side of the board (**Figure 1-2**), covered in a metal cap: the *system-on-chip* (SoC).



▲ **Figure 1-2: The Raspberry Pi's system-on-chip (SoC)**

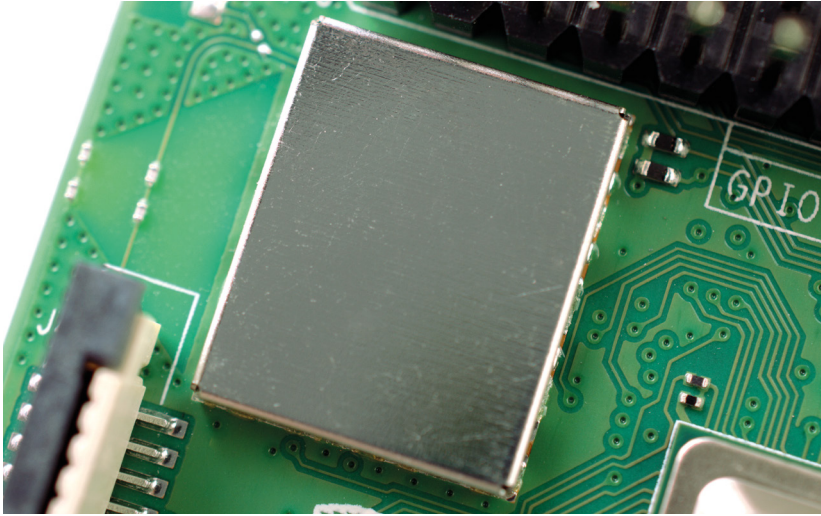
The name system-on-chip is a great indicator of what you would find if you prised the metal cover off: a silicon chip, known as an *integrated circuit*, which contains the bulk of the Raspberry Pi's system. This includes the *central processing unit* (CPU), commonly thought of as the 'brain' of a computer, and the *graphics processing unit* (GPU), which handles the visual side of things.

A brain is no good without memory, however, and just to side of the SoC you'll find exactly that: another chip, which looks like a small, black, plastic square (**Figure 1-3**). This is the Raspberry Pi's *random access memory* (RAM). When you're working on the Pi, it's the RAM that holds what you're doing; only when you save your work will it be written to the microSD card. Together, these components form the Pi's volatile and non-volatile memories: the volatile RAM loses its contents whenever the Pi is powered off, while the non-volatile microSD card keeps its contents.



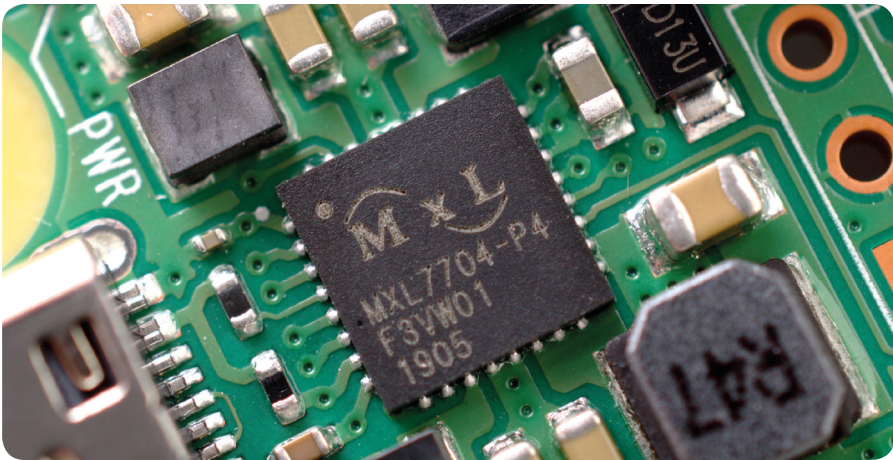
▲ **Figure 1-3: The Raspberry Pi's random access memory (RAM)**

At the top right of the board you'll find another metal lid (**Figure 1-4**, overleaf) covering the *radio*, the component which gives the Raspberry Pi the ability to communicate with devices wirelessly. The radio itself acts as two main components, in fact: a *WiFi radio*, for connecting to computer networks; and a *Bluetooth radio*, for connecting to peripherals like mice and for sending data to or receiving data from nearby smart devices like sensors or smartphones.



▲ **Figure 1-4: The Raspberry Pi's radio module**

Another black, plastic-covered chip can be seen to the bottom edge of the board, just behind the middle set of USB ports. This is the *USB controller*, and is responsible for running the four USB ports. Next to this is an even smaller chip, the *network controller*, which hands the Raspberry Pi's Ethernet network port. A final black chip, smaller than the rest, can be found a little bit above the USB Type-C power connector to the upper-left of the board (**Figure 1-5**); this is known as a *power management integrated circuit (PMIC)*, and handles turning the power that comes in from the micro USB port into the power the Pi needs to run.



▲ **Figure 1-5: The Raspberry Pi's power management integrated circuit (PMIC)**

Don't worry if this seems like a lot to take in; you don't need to know what each component is or where to find it on the board in order to use the Raspberry Pi.

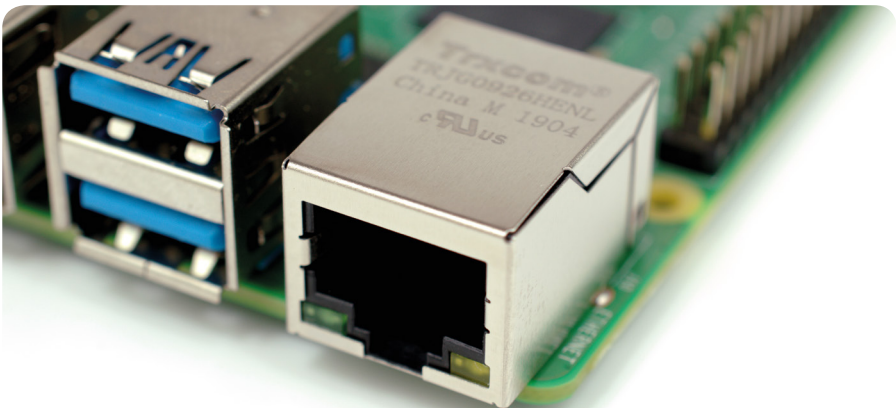
The Raspberry Pi's ports

The Raspberry Pi has a range of ports, starting with four *Universal Serial Bus (USB)* ports (**Figure 1-6**) to the middle and right-hand side of the bottom edge. These ports let you connect any USB-compatible peripheral, from keyboards and mice to digital cameras and flash drives, to the Pi. Speaking technically, there are two types of USB ports: the ones with black parts inside are USB 2.0 ports, based on version two of the Universal Serial Bus standard; the ones with blue parts are faster USB 3.0 ports, based on the newer version three.



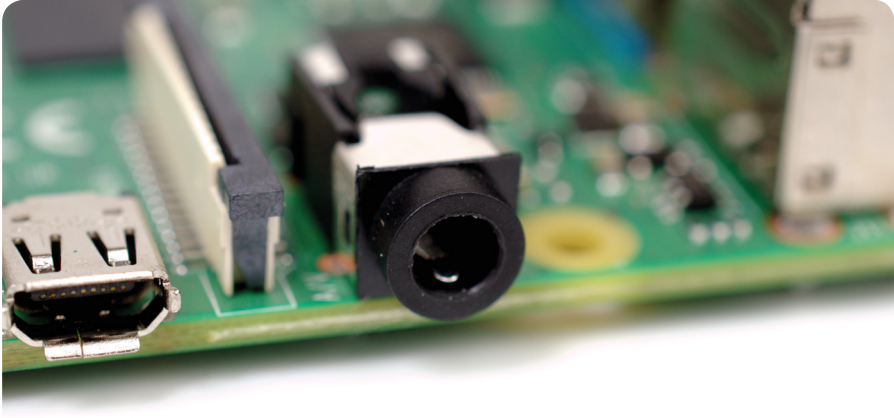
▲ **Figure 1-6:** The Raspberry Pi's USB ports

To the right of the USB ports is an *Ethernet port*, also known as a *network port* (**Figure 1-7**). You can use this port to connect the Raspberry Pi to a wired computer network using a cable with what is known as an RJ45 connector on its end. If you look closely at the Ethernet port, you'll see two light-emitting diodes (LEDs) at the bottom; these are status LEDs, and let you know that the connection is working.



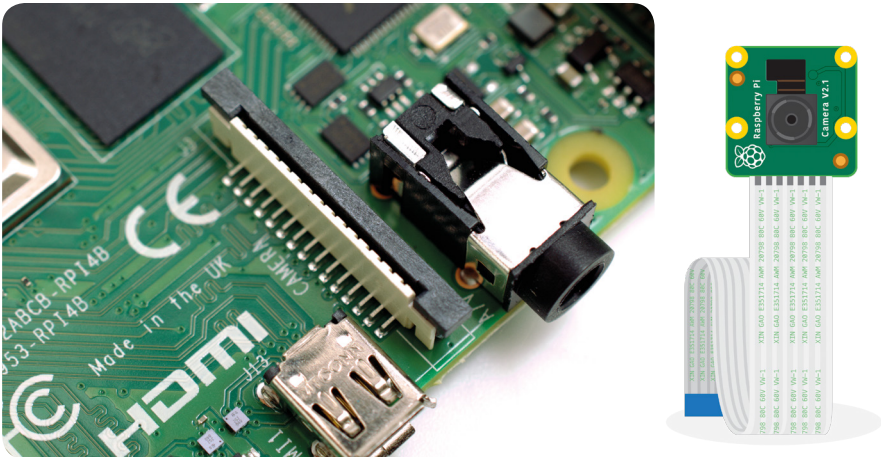
▲ **Figure 1-7:** The Raspberry Pi's Ethernet port

Just above the Ethernet port, on the left-hand edge of the Raspberry Pi, is a 3.5 mm *audio-visual (AV) jack* (**Figure 1-8**). This is also known as the *headphone jack*, and it can be used for that exact purpose – though you’ll get better sound connecting it to amplified speakers rather than headphones. It has a hidden, extra feature, though: as well as audio, the 3.5 mm AV jack carries a video signal which can be connected to TVs, projectors, and other displays that support a *composite video signal* using a special cable known as a *tip-ring-ring-sleeve (TRRS)* adapter.



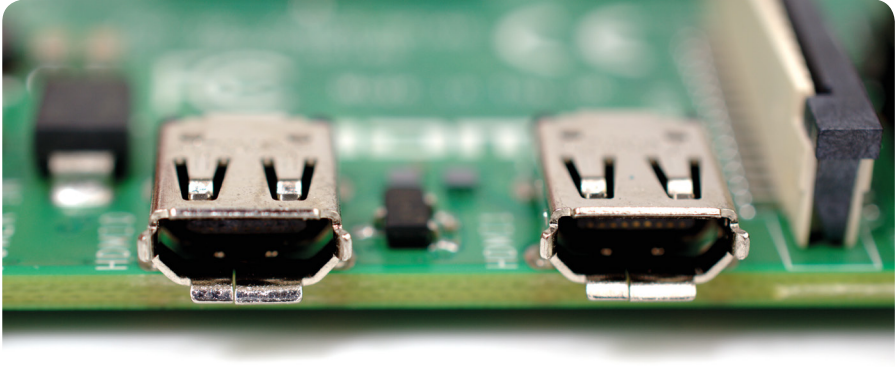
▲ **Figure 1-8:** The Raspberry Pi's 3.5 mm AV jack

Directly above the 3.5 mm AV jack is a strange-looking connector with a plastic flap which can be pulled up; this is the *camera connector*, also known as the *Camera Serial Interface (CSI)* (**Figure 1-9**). This allows you to use the specially designed Raspberry Pi Camera Module (about which you'll learn more in **Chapter 8, The Raspberry Pi Camera Module**.)



▲ **Figure 1-9:** The Raspberry Pi's camera connector

Above that, still on the left-hand edge of the board, are the *micro High Definition Multimedia Interface (micro-HDMI) ports*, which are a smaller version of the connectors you'll find on a games console, set-top box, or TV (**Figure 1-10**). The multimedia part of its name tells you that it carries both audio and video signals, while high-definition tells you that you can expect excellent quality. You'll use these to connect the Raspberry Pi to one or two display devices: a computer monitor, TV, or projector.



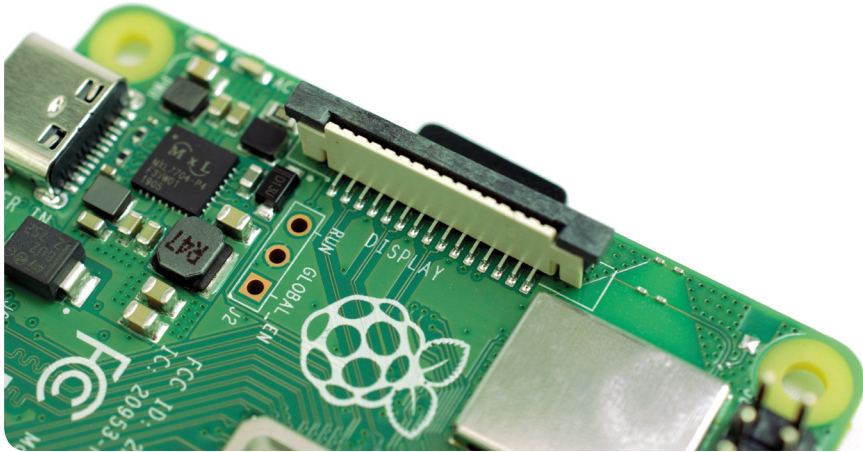
▲ **Figure 1-10:** The Raspberry Pi's micro-HDMI ports

Above the HDMI ports is a *USB Type-C power port* (**Figure 1-11**), which you'll use to connect the Raspberry Pi to a power source. The USB Type-C port is a common sight on smartphones, tablets, and other portable devices. While you could use a standard mobile charger to power the Pi, for best results you should use the official Raspberry Pi USB Type-C Power Supply.

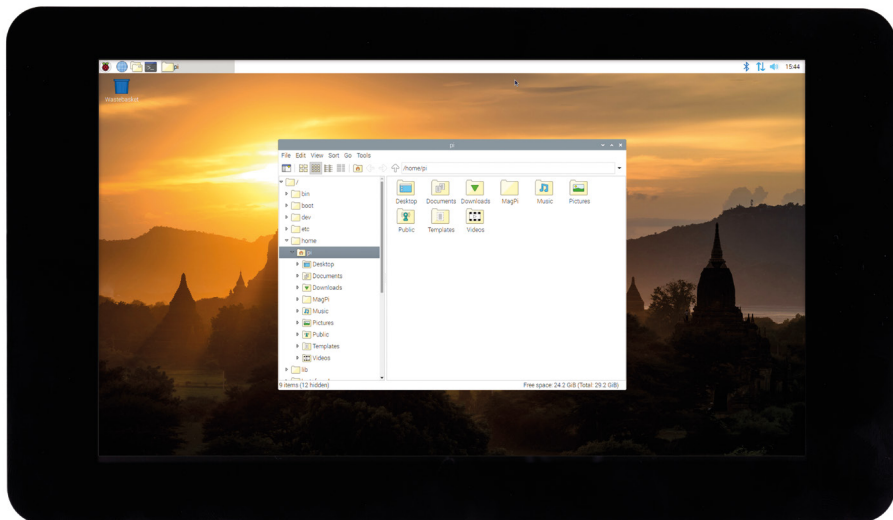


▲ **Figure 1-11:** The Raspberry Pi's USB Type-C power port

At the top edge of the board is another strange-looking connector (**Figure 1-12**), which at first glance appears to be identical to the camera connector. This, though, is the exact opposite: a *display connector*, or *Display Serial Interface (DSI)*, designed for use with the Raspberry Pi Touch Display (**Figure 1-13**).

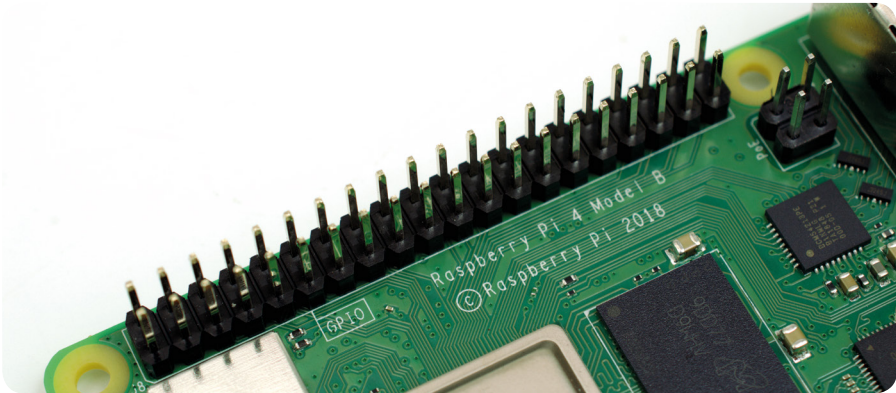


▲ **Figure 1-12:** The Raspberry Pi's display connector (DSI)



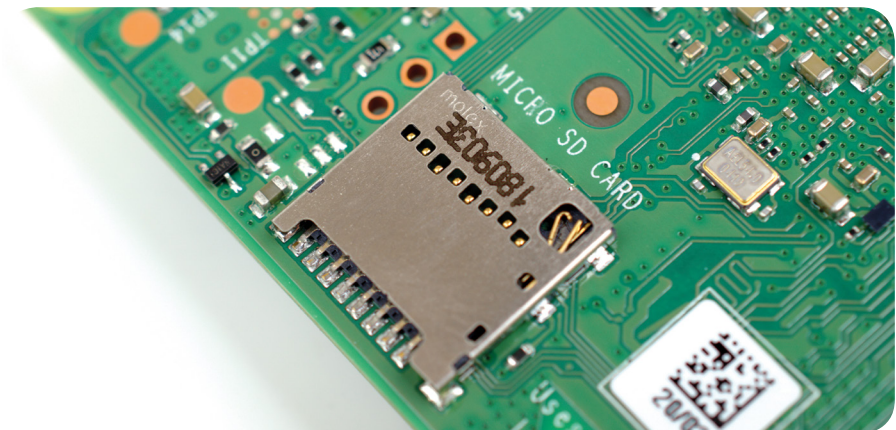
▲ **Figure 1-13:** The Raspberry Pi Touch Display

At the right-hand edge of the board you'll find 40 metal pins, split into two rows of 20 pins (**Figure 1-14**). This is the *GPIO* (*general-purpose input/output*) header, a feature of the Raspberry Pi used to talk to additional hardware from LEDs and buttons all the way to temperature sensors, joysticks, and pulse-rate monitors. You'll learn more about the GPIO header in **Chapter 6, Physical computing with Scratch and Python**. Just below and to the left of this header is another, smaller header with four pins: this is used to connect the Power over Ethernet (PoE) HAT, an optional add-on which lets the Raspberry Pi receive power from a network connection rather than the USB Type-C port.



▲ **Figure 1-14:** The Raspberry Pi's GPIO header

There's one final port on the Raspberry Pi, but you won't see it on the top. Turn the board over and you'll find a *microSD card connector* on the opposite side of the board to the display connector (**Figure 1-15**). This is the Raspberry Pi's storage: the microSD card inserted in here contains all the files you save, all the software you install, and the operating system that makes the Raspberry Pi run.



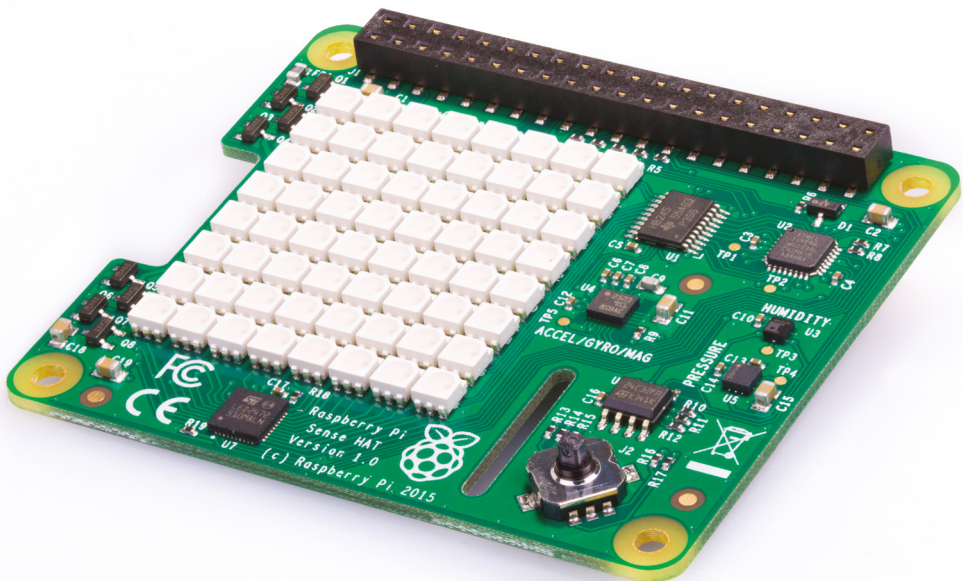
▲ **Figure 1-15:** The Raspberry Pi's microSD card connector

The Raspberry Pi's peripherals

A Raspberry Pi by itself can't do very much, just the same as a desktop computer on its own is little more than a door-stop. To work, the Raspberry Pi needs peripherals: at the minimum, you'll need a microSD card for storage; a monitor or TV so you can see what you're doing; a keyboard and mouse to tell the Pi what to do; and a 5 volt (5 V) USB Type-C power supply rated at 3 amps (3 A) or better. With those, you've got yourself a fully functional computer. You'll learn how to connect all these peripherals to your Raspberry Pi in **Chapter 2, Getting started with your Raspberry Pi**.

Those aren't the end of the peripherals you can use with your Pi, though. Official accessories produced by the Raspberry Pi Foundation include: the Raspberry Pi Case, which helps protect the Pi while you're using it without blocking your access to its various ports; the Camera Module, detailed in **Chapter 8, The Raspberry Pi Camera Module**; the Raspberry Pi Touch Display, which connects to the display port and provides both a video display and a tablet-style touchscreen interface; and the Sense HAT (**Figure 1-16**), a clever multifunctional add-on which is detailed in full in **Chapter 7, Physical computing with the Sense HAT**.

A wide assortment of third-party accessories are also available, ranging from kits to turn a Raspberry Pi into a laptop or tablet to add-ons which give it the ability to understand your speech and even talk back to you. While it's tempting to run out and fill a shopping trolley, though, remember that you'll need to learn to walk with your Raspberry Pi before taking on the hardware equivalent of a marathon!



▲ **Figure 1-16: The Sense HAT**

Chapter 2

Getting started with your Raspberry Pi

Discover the essential items you'll need for your Raspberry Pi and how to connect them all to get it set up and working

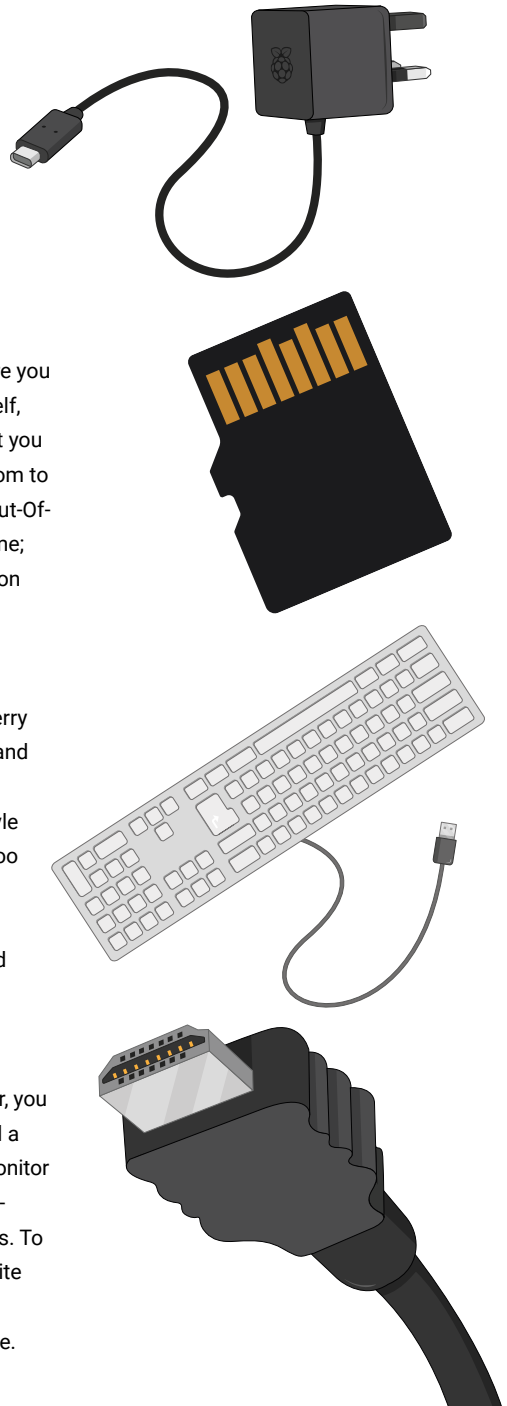


The Raspberry Pi has been designed to be as quick and easy to set up and use as possible, but – like any computer – it relies on various external components, called *peripherals*. While it's easy to take a look at the bare circuit board of the Raspberry Pi – which looks significantly different to the encased, closed-off computers you may be used to – and worry things are about to get complicated, that's not the case. You can be up and running with the Raspberry Pi in well under ten minutes simply by following the steps in this guide.

If you have received this book as part of the Raspberry Pi Starter Kit, then you'll already have almost everything you'll need to get started: all you need to provide is a computer monitor or TV with an HDMI connection – the same type of connector used by set-top boxes, Blu-ray players, and games consoles – so you can see what the Raspberry Pi is doing.

If you don't have the Raspberry Pi Starter Kit, then in addition to the Raspberry Pi 4 Model B you'll need:

- **USB power supply** – A 5 V power supply rated at 3 amps (3 A) and with a USB Type-C connector. The Official Raspberry Pi Power Supply is the recommended choice, as it can cope with the quickly switching power demands of the Pi.
- **microSD card with NOOBS** – The microSD card acts as the Raspberry Pi's permanent storage; all the files you create and software you install, along with the operating system itself, are stored on the card. An 8GB card will get you started, though a 16GB one offers more room to grow. Using a card with NOOBS, the New Out-Of-Box Software, pre-installed will save you time; otherwise see **Appendix A** for instructions on installing NOOBS on a blank card.
- **USB keyboard and mouse** – The keyboard and mouse allow you to control the Raspberry Pi. Almost any wired or wireless keyboard and mouse with a USB connector will work with the Raspberry Pi, though some 'gaming' style keyboards with colourful lights may draw too much power to be used reliably.
- **Micro-HDMI cable** – This carries sound and images from the Raspberry Pi to your TV or monitor. One end of the cable has a micro-HDMI connector for the Pi; the other has a full-size HDMI connector for your display. Or, you can use a micro-HDMI to HDMI adapter and a standard, full-size HDMI cable. If using a monitor without an HDMI socket, you can buy micro-HDMI to DVI-D, DisplayPort, or VGA adapters. To connect to an older TV which uses composite video or has a SCART socket, use a 3.5 mm tip-ring-ring-sleeve (TRRS) audio/video cable.



The Raspberry Pi is safe to use without a case, providing you don't place it on a metal surface which could conduct electricity and cause a short-circuit. An optional case, however, can provide additional protection; the Starter Kit includes the Official Raspberry Pi Case, while third-party cases are available from all good stockists.

If you want to use the Raspberry Pi on a wired network, rather than a wireless (WiFi) network, you'll also need a network cable. This should be connected at one end to your network's switch or router. If you're planning to use the Raspberry Pi's built-in wireless radio, you won't need a cable; you will, however, need to know the name and key or passphrase for your wireless network.

Setting up the hardware

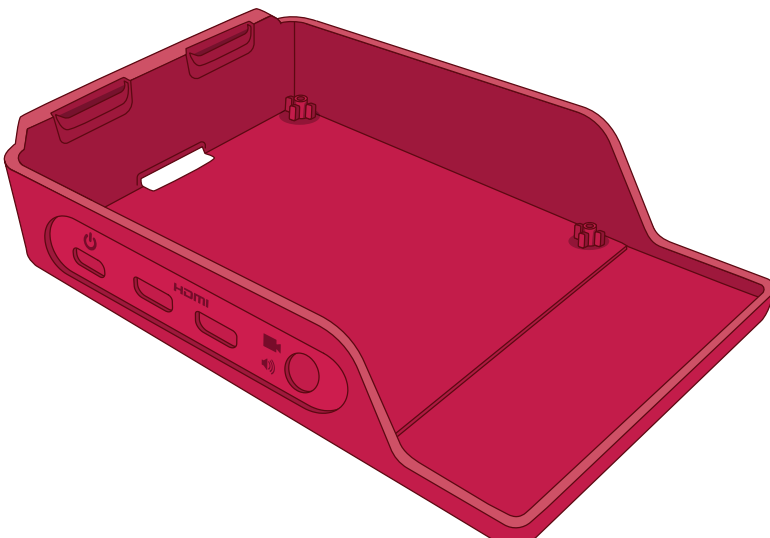
Begin by unpacking your Raspberry Pi from its box. The Raspberry Pi is a robust piece of hardware, but that doesn't mean it's indestructible: try to get into the habit of holding the board by the edges, rather than on its flat sides, and be extra careful around the raised metal pins. If these pins are bent, at best it'll make using add-on boards and other extra hardware difficult and, at worst, can cause a short-circuit that will damage the Raspberry Pi.

If you haven't done so already, have a look at **Chapter 1, Getting to know your Raspberry Pi**, for details on exactly where the various ports are and what they do.

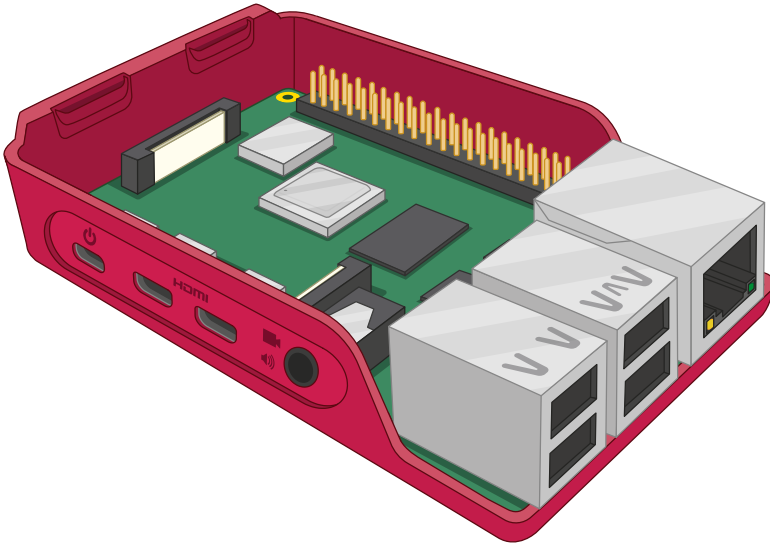
Assembling the case

If you're installing your Pi in a case, it should be your first step. If you're using the Official Raspberry Pi Case, begin by splitting it into its two individual pieces: the red base and white lid.

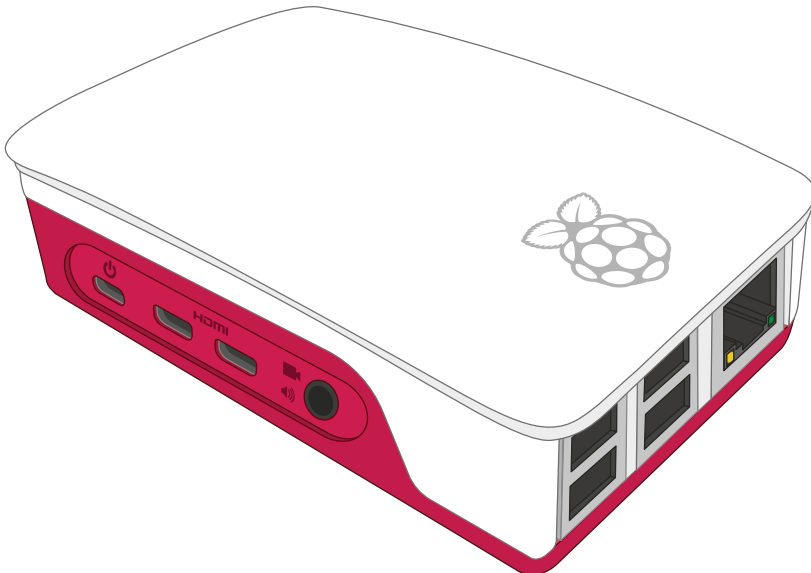
- 1 Take the base and hold it so that the raised end is to your left and the lower end to your right.**



- 2** Holding the Pi (with no microSD card inserted) by its USB and Ethernet ports, at a slight angle, slot its connectors (USB Type-C, 2 × micro-HDMI, and 3.5 mm) into their holes in the side of the base, then gently lower the other side down so it sits flat.

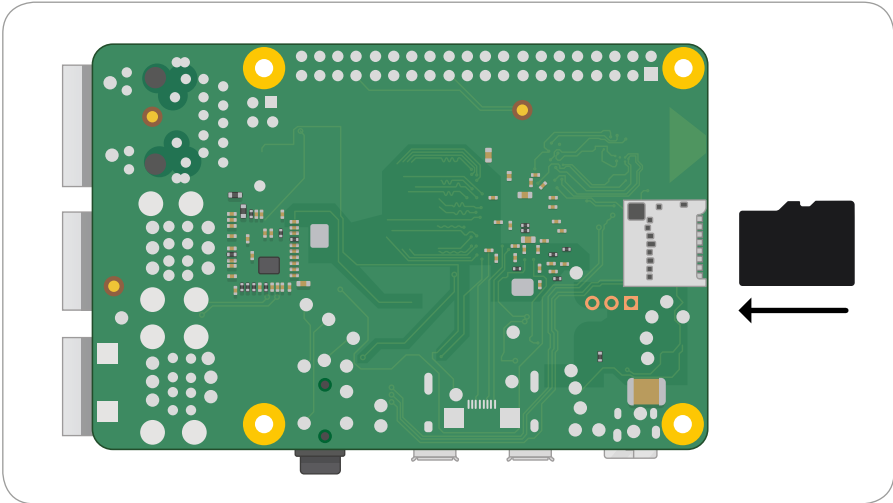


- 3** Take the white lid and place the two clips at the left into the matching holes on the left of the base, above the microSD card slot. When they're in place, push the right-hand side (above the USB ports) down until you hear a click.

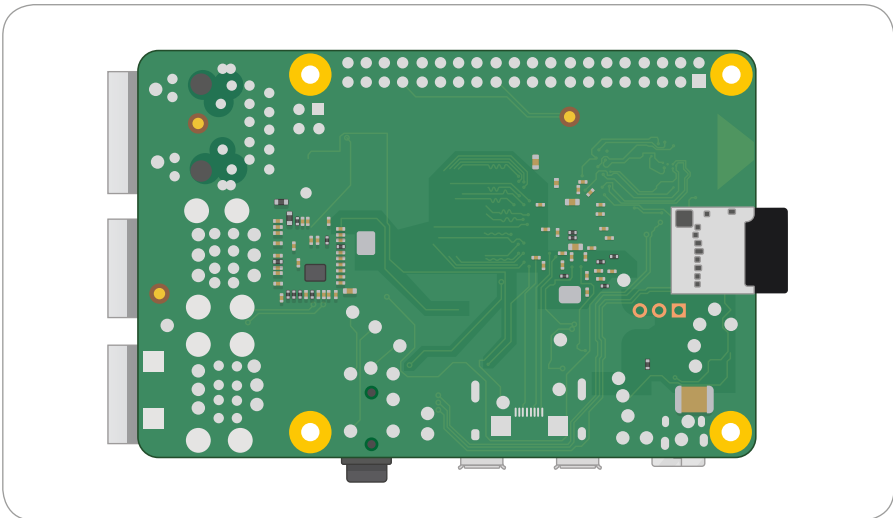


Connecting the microSD card

To install the microSD card, which is the Raspberry Pi's storage, turn the Raspberry Pi (in its case if using one) over and slide the card into the microSD slot with the label facing away from the Pi. It can only go in one way, and should slide home without too much pressure.



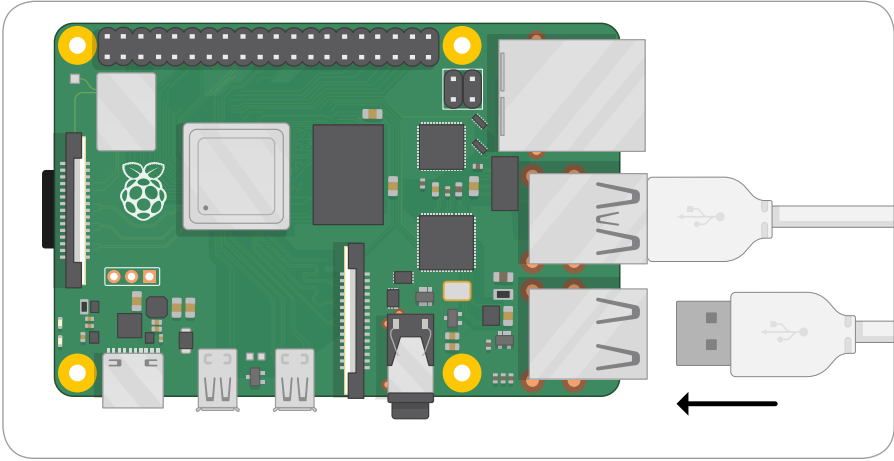
The microSD card will slide into the connector, then stop without a click.



If you want to remove it again in the future, simply grip the end of the card and pull it gently out. If you're using an older model of Raspberry Pi, you'll need to give the card a gentle push first to unlock it; this isn't necessary with a Raspberry Pi 3 or 4.

Connecting a keyboard and mouse

Connect the keyboard's USB cable to any of the four USB ports (2.0 or 3.0) on the Raspberry Pi. If you're using the Official Raspberry Pi Keyboard, there's a USB port on the back for the mouse; if not, just connect your mouse's USB cable from your mouse to another USB port on the Raspberry Pi.



The USB connectors for the keyboard and mouse should slide home without too much pressure; if you're having to force the connector in, there's something wrong. Check that the USB connector is the right way up!

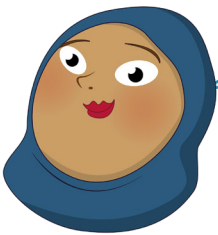
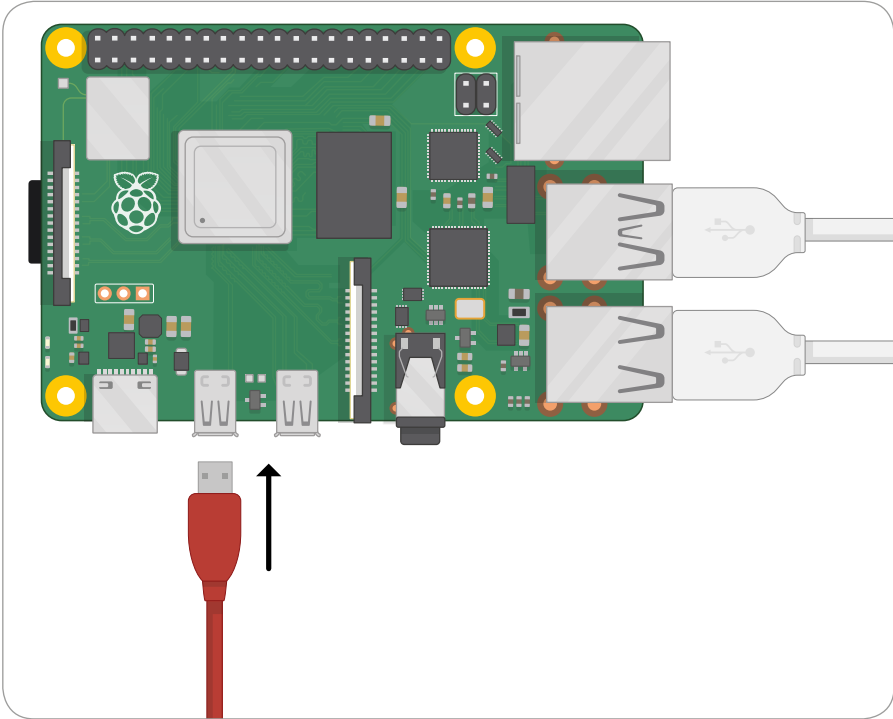


KEYBOARD & MOUSE

The keyboard and mouse act as your main means of telling the Raspberry Pi what to do; in computing, these are known as *input devices*, in contrast with the display which is an *output device*.

Connecting a display

Take the micro-HDMI cable and connect the smaller end to the micro-HDMI port closest to the USB Type-C port on your Raspberry Pi, and the other end to your display. If your display has more than one HDMI port, look for a port number next to the connector itself; you'll need to switch the TV to this input to see the Pi's display. If you can't see a port number, don't worry: you can simply switch through each input in turn until you find the Pi.

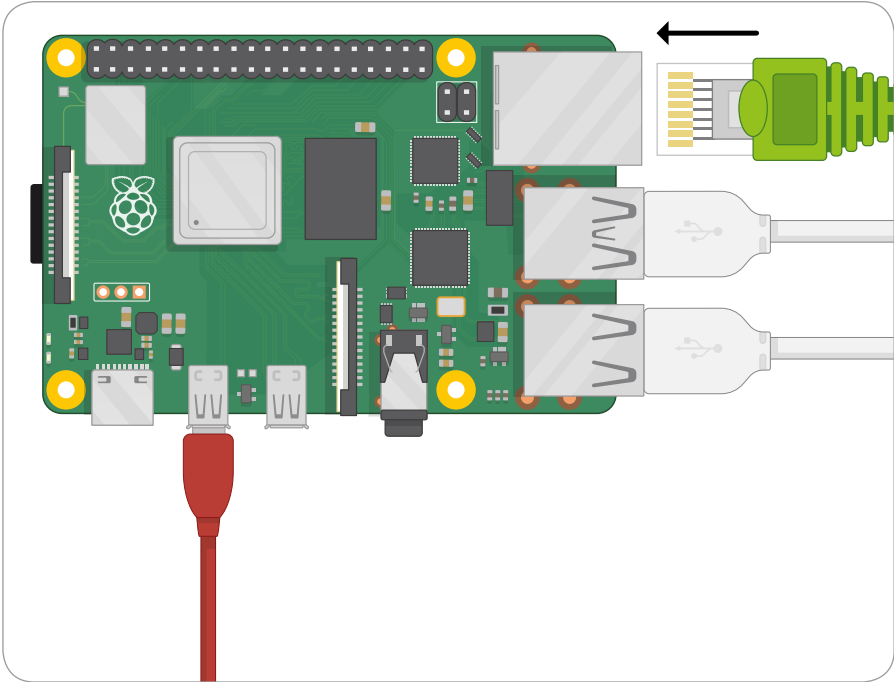


TV CONNECTION

If your TV or monitor doesn't have an HDMI connector, that doesn't mean you can't use the Raspberry Pi. Adapter cables, available from any electronics stockist, will allow you to convert the micro-HDMI port on the Raspberry Pi to DVI-D, DisplayPort, or VGA for use with older computer monitors; these are simply connected to the Pi's micro-HDMI port, then a suitable cable used to connect the adapter cable to the monitor. If your TV has only a composite video or SCART input, you can purchase 3.5 mm tip-ring-ring-sleeve (TRRS) adapter cables and composite-to-SCART adapters which connect to the 3.5 mm AV jack.

Connecting a network cable (optional)

To connect your Raspberry Pi to a wired network, take a network cable – known as an Ethernet cable – and push it into the Pi's Ethernet port, with the plastic clip facing downwards, until you hear a click. If you need to remove the cable, just squeeze the plastic clip inwards towards the plug and gently slide the cable free again.

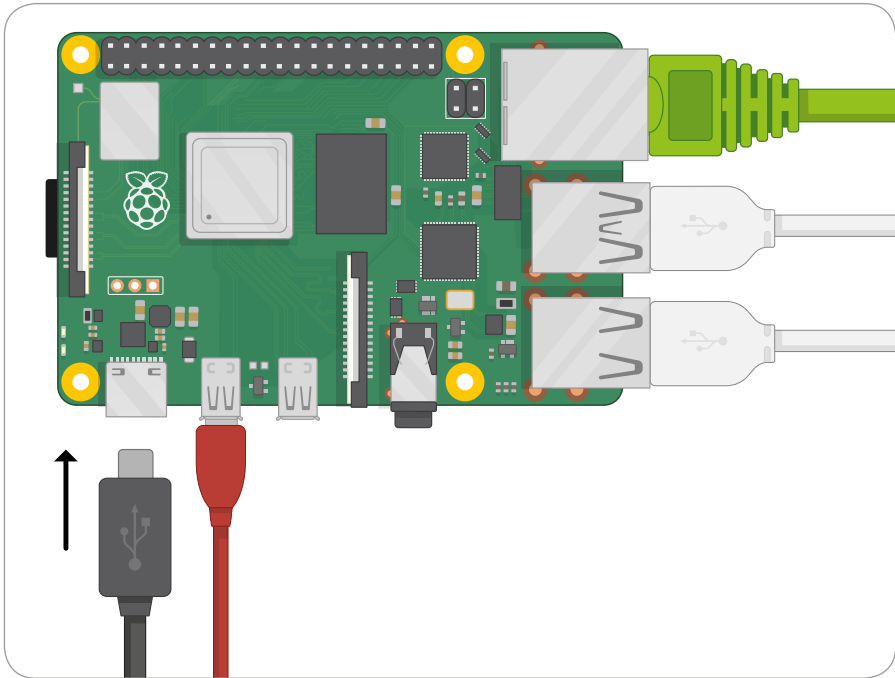


The other end of your network cable should be connected to any free port on your network hub, switch, or router in the same way.

Connecting a power supply

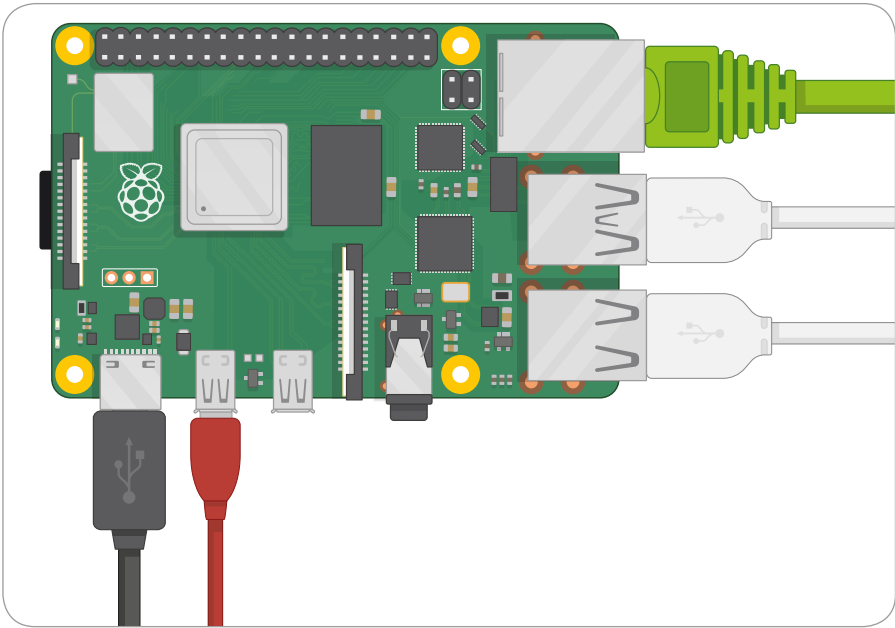
Connecting the Raspberry Pi to a power supply is the very last step in the hardware setup process, and it's one you should do only when you're ready to set up its software: the Pi does not have a power switch and will turn on as soon as it is connected to a live power supply.

First, connect the USB Type-C end of the power supply cable to the USB Type-C power connector on the Raspberry Pi. It can go in either way around and should slide home gently. If your power supply has a detachable cable, make sure the other end is plugged into the body of the power supply.



Finally, connect the power supply to a mains socket and switch the socket on; the Raspberry Pi will immediately start running.

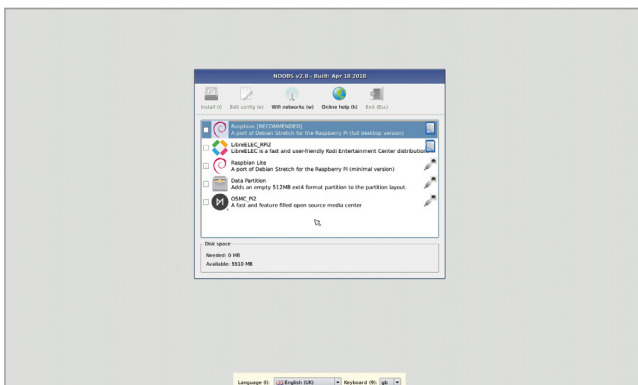
Congratulations: you have put your Raspberry Pi together!



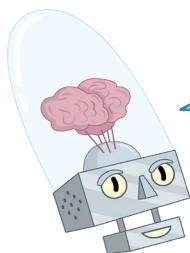
Setting up the software

Before you can begin using the Raspberry Pi in earnest, you'll need to set up its software – in particular its operating system, the software which controls what the Pi can do. NOOBS, the New Out-Of-Box Software, is designed to make this as easy as possible, allowing you to choose from several different operating systems and install them automatically. Better still, you can do all this in little more than a few clicks of the mouse.

When the Pi is first switched on, or booted, with a fresh installation of NOOBS on its microSD card, you'll see a screen with the Raspberry Pi logo on it and a small progress window at the upper-left. After a short pause, which can take up to a minute the first time you use the NOOBS microSD card, you'll see the screen shown in **Figure 2-1**.



◀ **Figure 2-1:**
The NOOBS menu
without any operating
systems installed

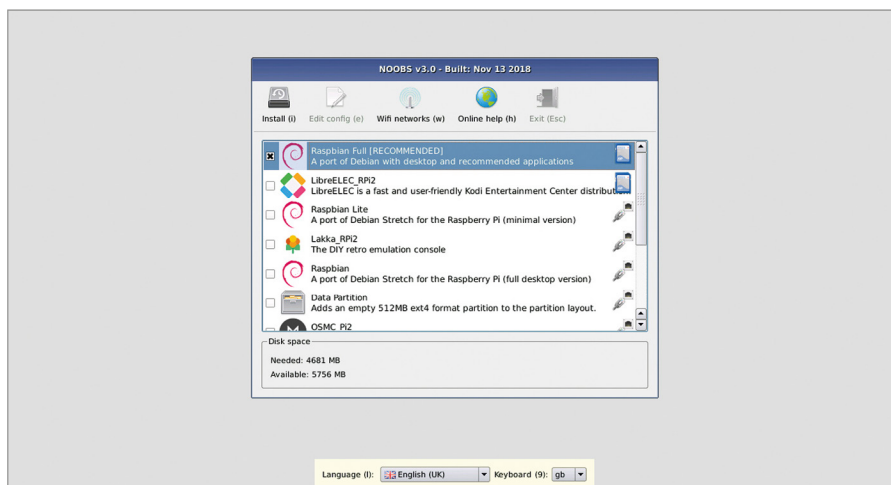


NO PICTURE?

If you can't see the Raspberry Pi on your display, check you are using the correct input. If your TV or monitor has more than one HDMI input, switch through each in turn using the 'Source' or 'Input' button until you see the NOOBS menu.

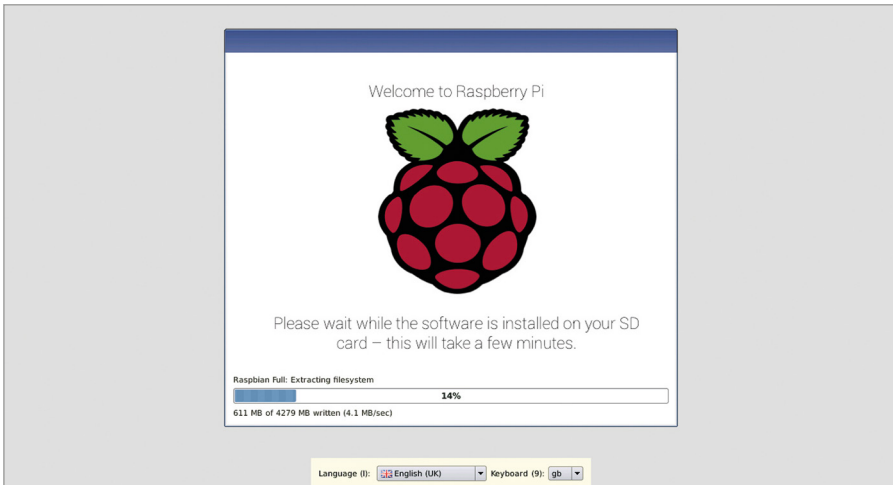
This is the NOOBS menu, a system which lets you choose the operating system to run on your Pi. Two operating systems are included with NOOBS as standard: Raspbian, a version of the Debian Linux operating system tailored specifically for the Raspberry Pi; and LibreELEC, a version of the Kodi Entertainment Centre software. If the Pi is connected to the network – either through a wired connection or using the 'Wifi networks (w)' option from the top bar of icons – you can also download and install other operating systems.

To begin installing an operating system, use the mouse to put a cross in the box to the left of Raspbian Full: point the cursor at the white box and click once with the left mouse button. When you've done so, you'll see that the 'Install (i)' menu icon is no longer greyed-out; this lets you know that your operating system is ready to install (**Figure 2-2**).



▲ **Figure 2-2:** Choosing an operating system to install through NOOBS

Click the 'Install (i)' icon once with the left mouse button and you'll see a warning message telling you that installing the operating system will overwrite any data currently stored on the microSD card – not counting NOOBS itself, which stays intact. Click 'Yes' and the installation process will begin (**Figure 2-3**).



▲ **Figure 2-3: Installing the Raspbian operating system**

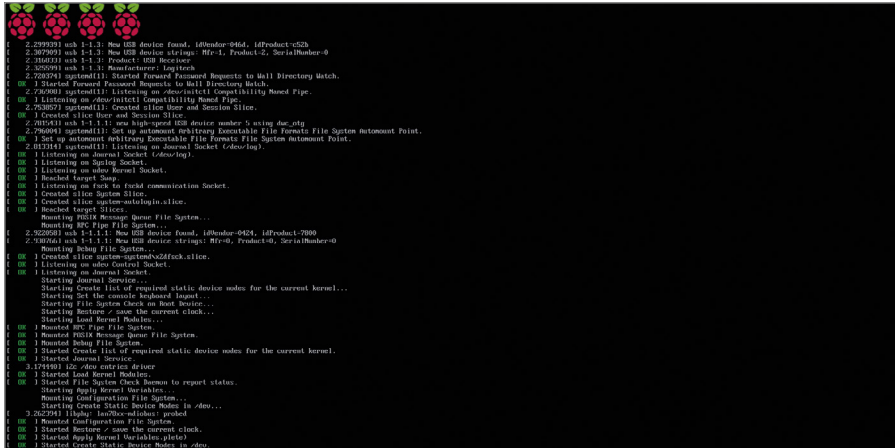
The installation process can take anything from 10 to 30 minutes, depending on the speed of your microSD card. As the operating system is installed, progress is shown in a bar along the bottom of the window, you'll see a slide show highlighting some of its key features; you'll learn more about these, and the operating system itself, in **Chapter 3, Using your Raspberry Pi**.



WARNING!

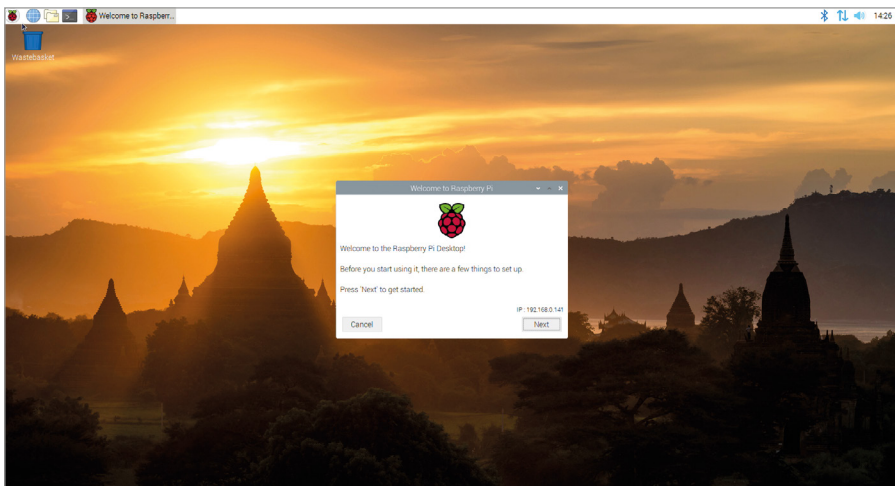
It's important that the installation isn't interrupted as this has a high likelihood of damaging the software, a process known as *data corruption*. Do not remove the microSD card or unplug the power cable while the operating system is being installed; if something does happen to interrupt the installation, unplug the Pi from its power supply, then hold down the **SHIFT** key on the keyboard as you connect the Raspberry Pi back up to its power supply to bring the NOOBS menu back up. This is known as *recovery mode*, and is a great way to restore a Pi whose software has been corrupted to working order again. It also allows you to enter the NOOBS menu after a successful installation, to reinstall the operating system, or install one of the other operating systems.

When the installation has finished, a window will pop up with an 'OK' button; click this and the Pi will restart into its freshly installed operating system. You'll see a lot of text scrolling up the screen (**Figure 2-4, overleaf**); these are known as the boot messages, and the first time you boot into Raspbian it can take a minute or two as it adjusts itself to make the best use of the free space on your microSD card. The next time you boot, things will go more quickly.



▲ **Figure 2-4: The Raspbian boot messages**

Finally, you'll briefly see a window with the Raspberry Pi logo on it before the Raspbian desktop and setup wizard appears, as in **Figure 2-5**. Your operating system is now fully installed and ready to be configured, which you'll learn to do in **Chapter 3, Using your Raspberry Pi**.



▲ **Figure 2-5: The Raspbian desktop**

