

Tutorial 1: Preparing the Raspberry Pi Sentry

Nathan Robinson

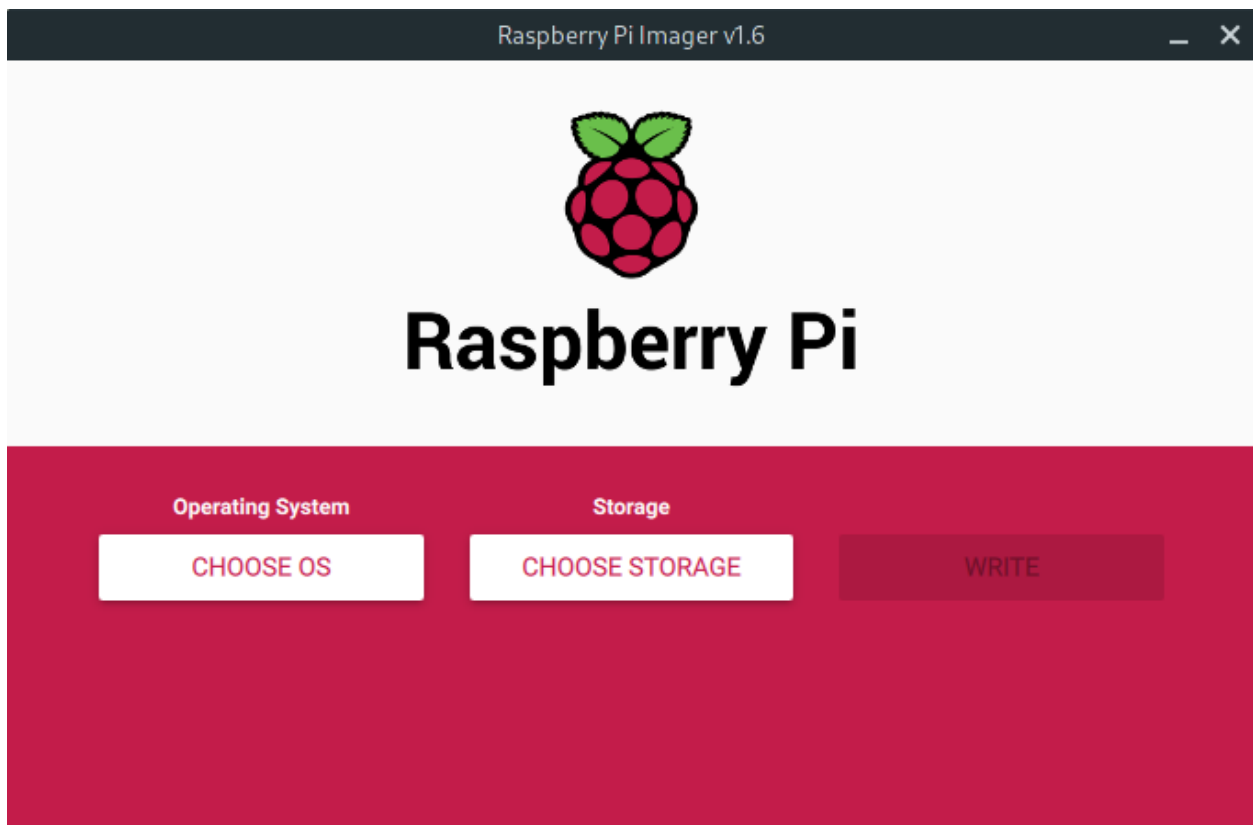
March 22, 2021

If you already have a Raspberry Pi running the latest Raspberry Pi OS with support enabled for the camera and I2C, please skip to **Step 7**.

Step 0: Install Raspberry Pi OS using Raspberry Pi Imager

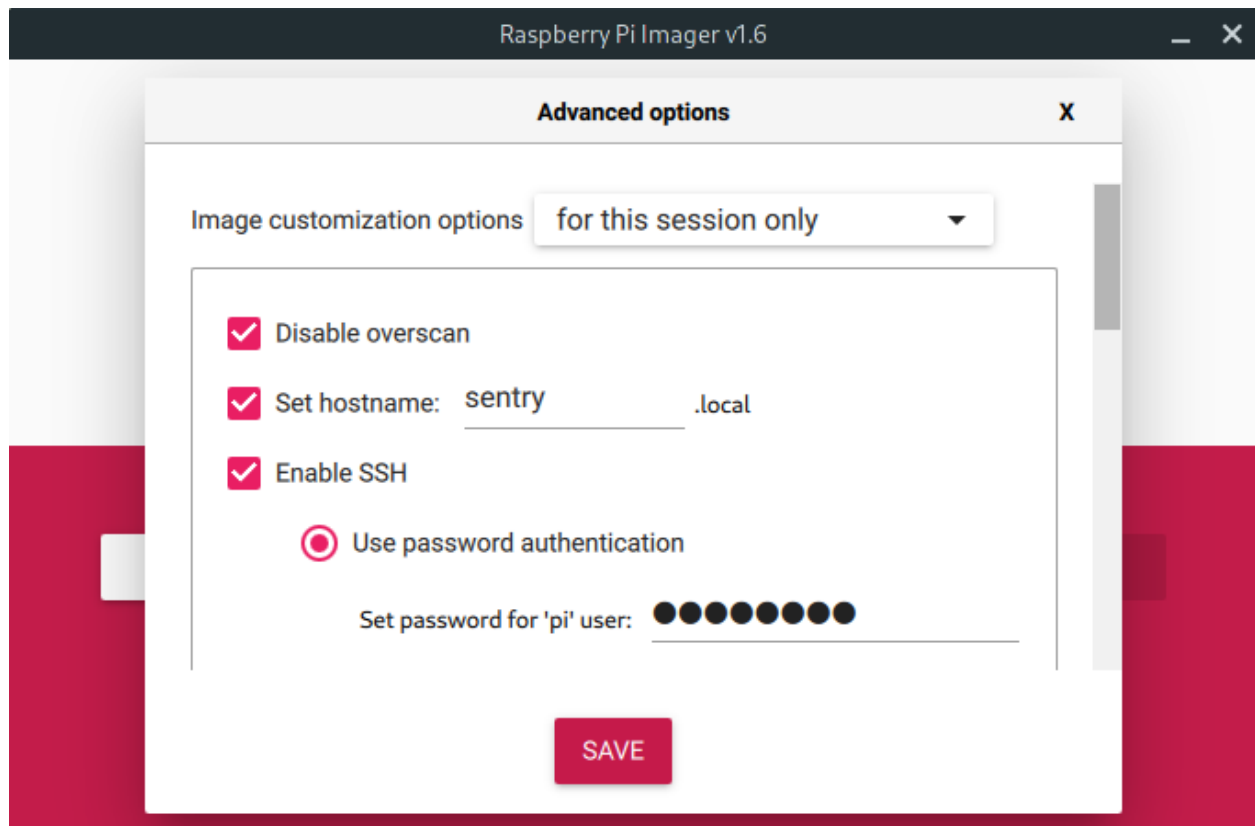
The easiest and quickest way to get the Raspberry Pi up and running is to use the Raspberry Pi Imager which is available from: <https://www.raspberrypi.org/software/>

After downloading Raspberry Pi Imager start the application. When presented with the following window press SHIFT-CTRL-X on Windows and Linux or SHIFT-CMD-X on Mac to open the customizations menu:

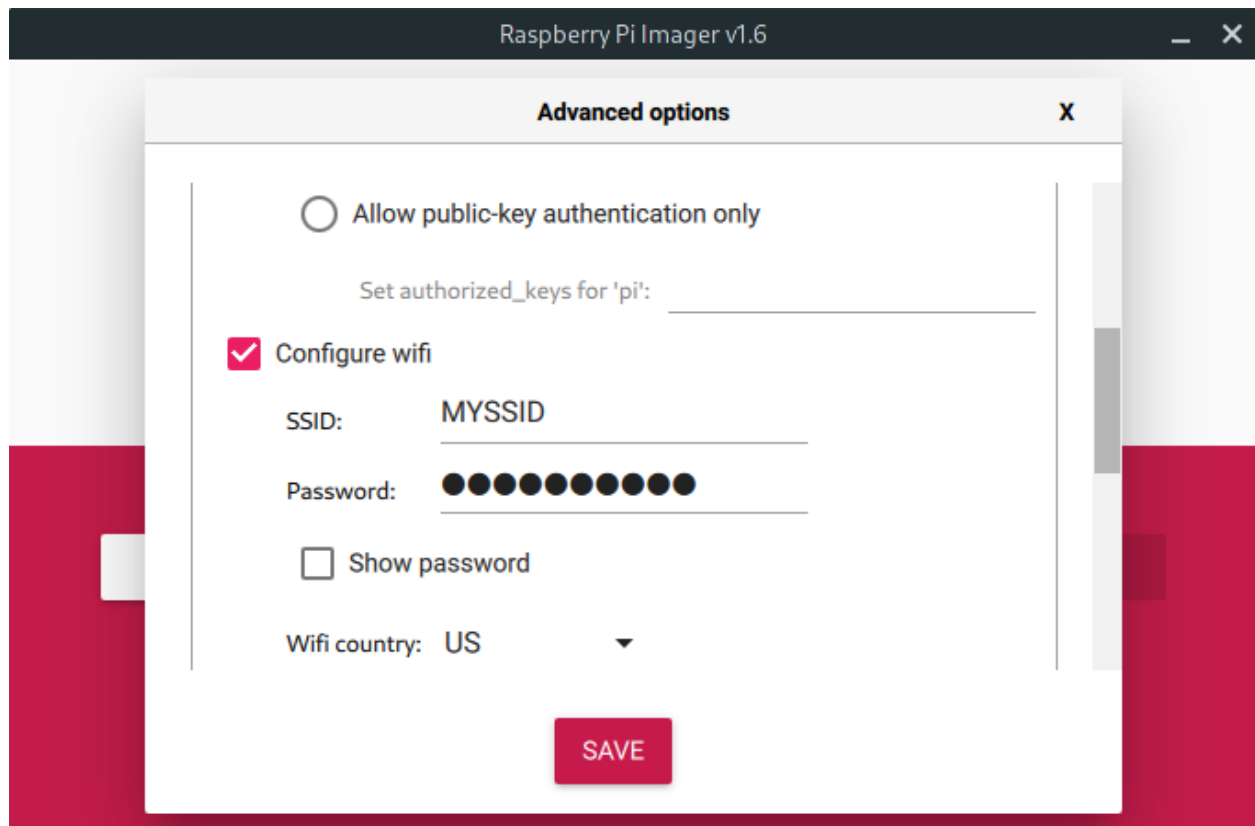


Check the box to **Disable overscan** and the box to **Set hostname**. For this tutorial we'll use **sentry** as the hostname.

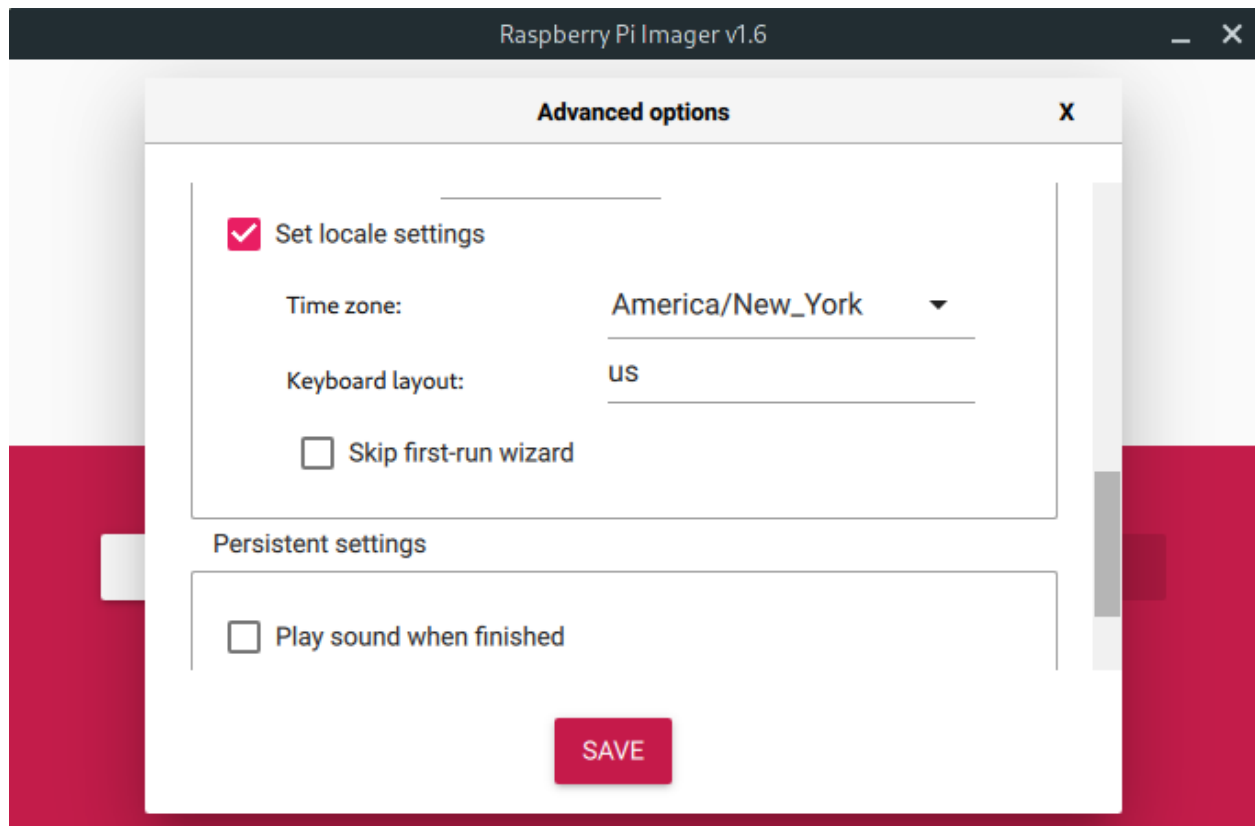
Next, check the box to **Enable SSH** and choose **Use password authentication**. Choose a password.



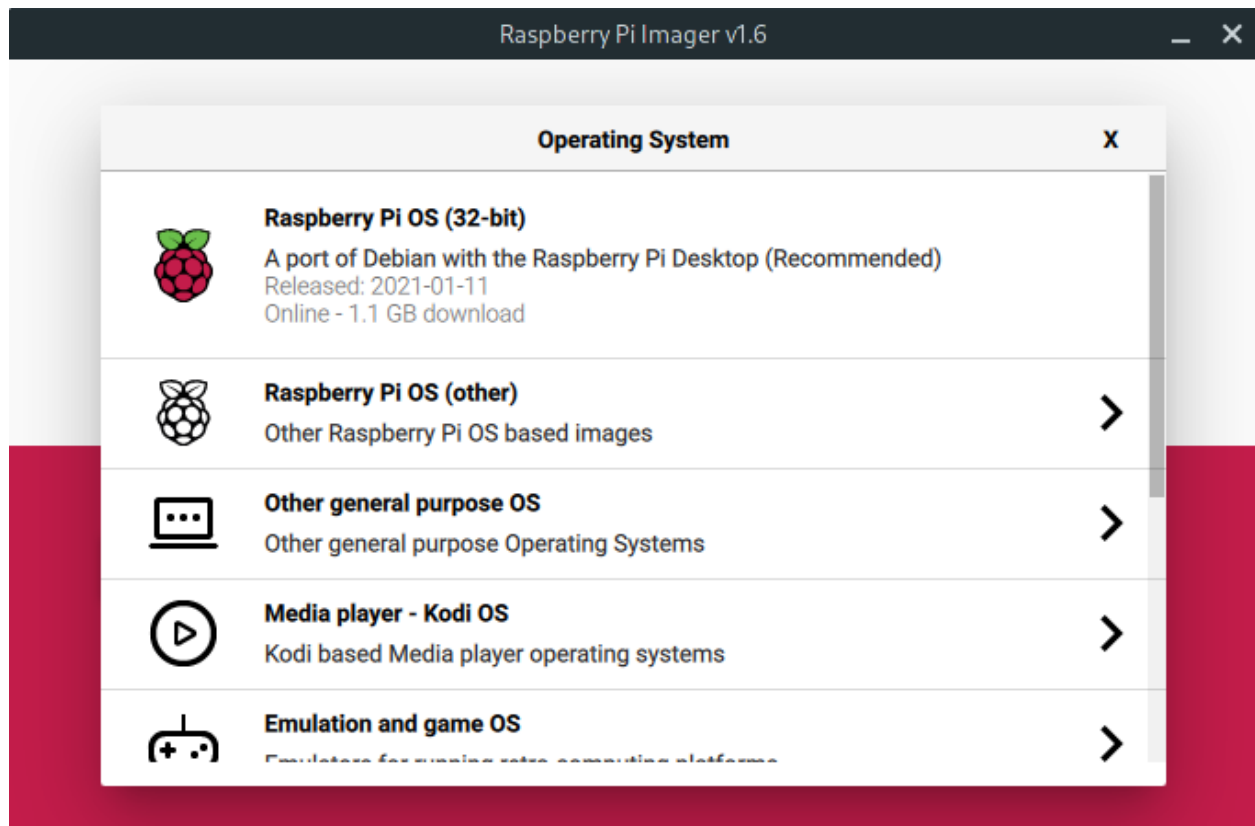
Next, check the box to **Configure wifi** and enter your SSID and password. Change the **Wifi country** to US.



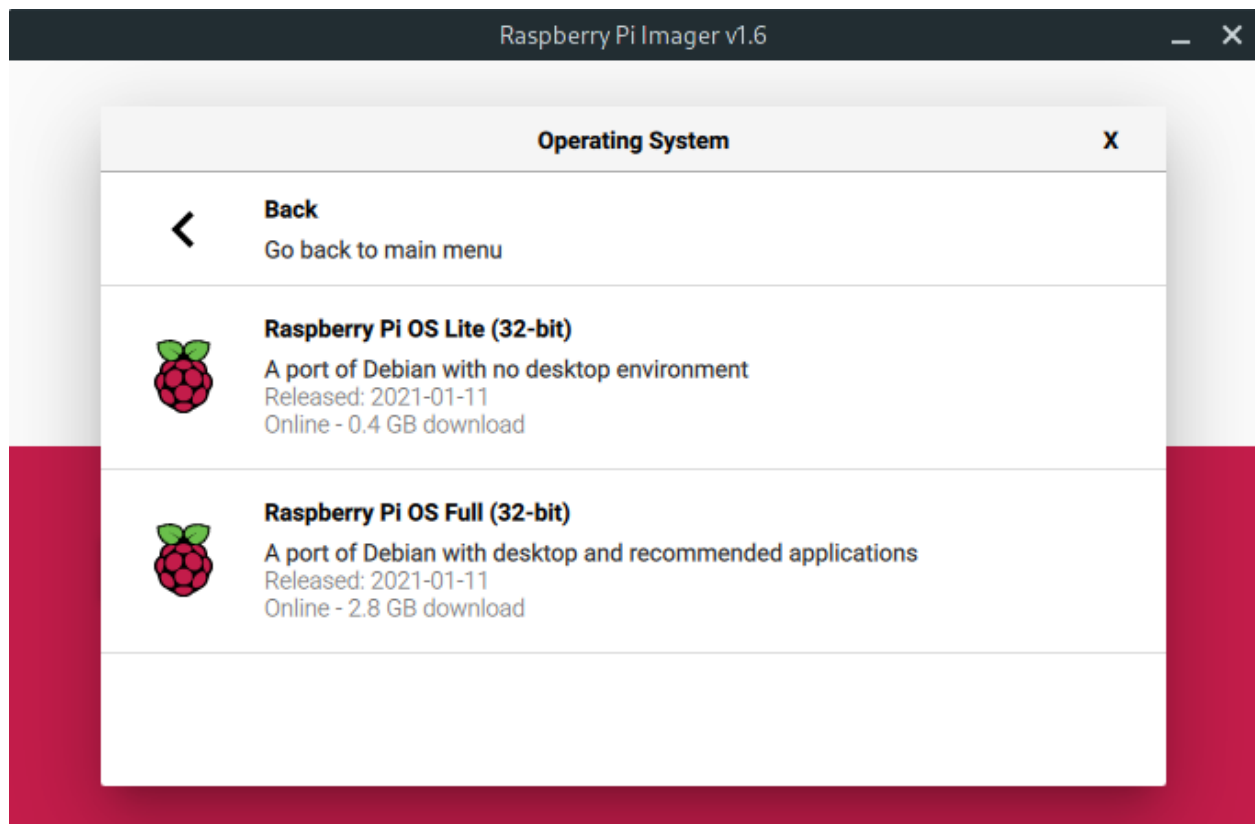
Next, check the box to `Set locale settings`. The `America/New_York` timezone and `us` keyboard layout are the default and work well for me.



Click **SAVE** to continue. Next, click the **CHOOSE OS** button. There are many operating systems to choose from, but Raspberry Pi OS Lite fits our needs best for this application since it is the most lightweight.



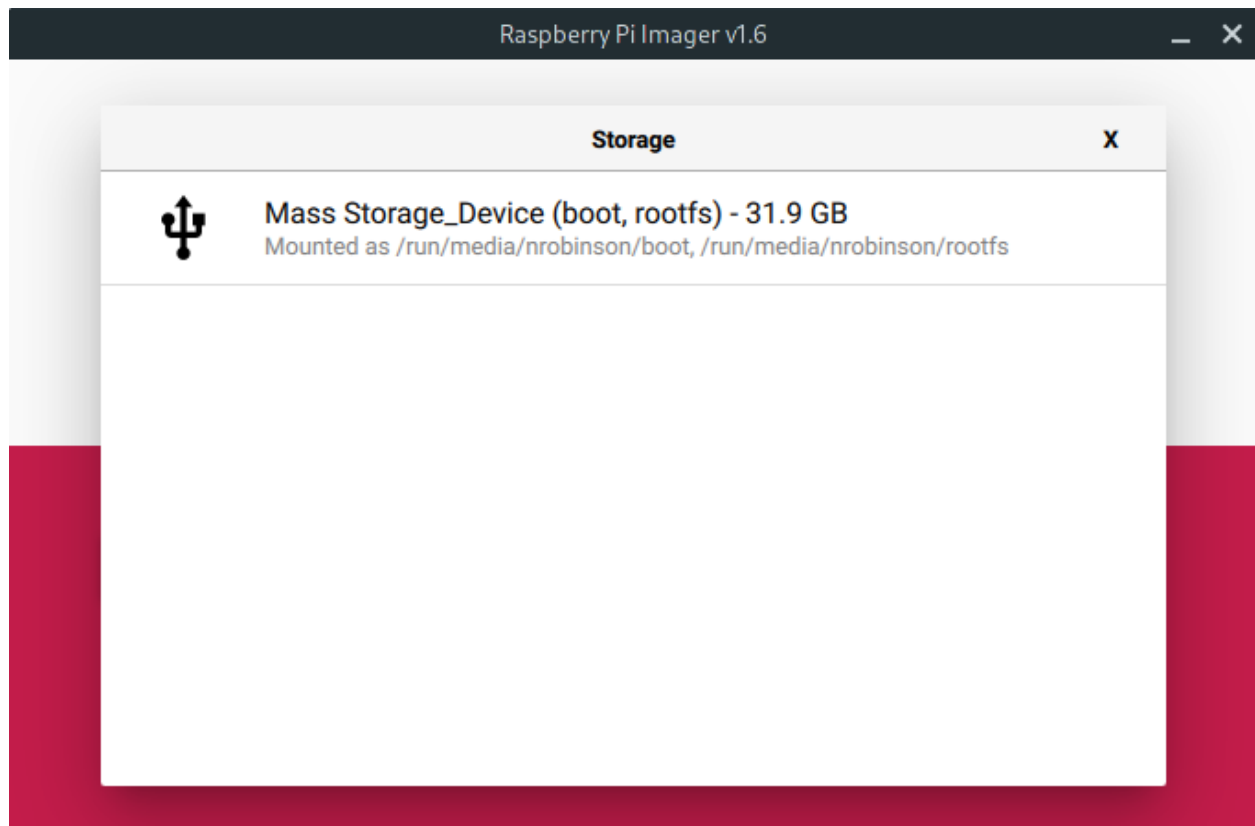
Click Raspberry Pi OS (other), and then select Raspberry Pi OS Lite (32-bit).



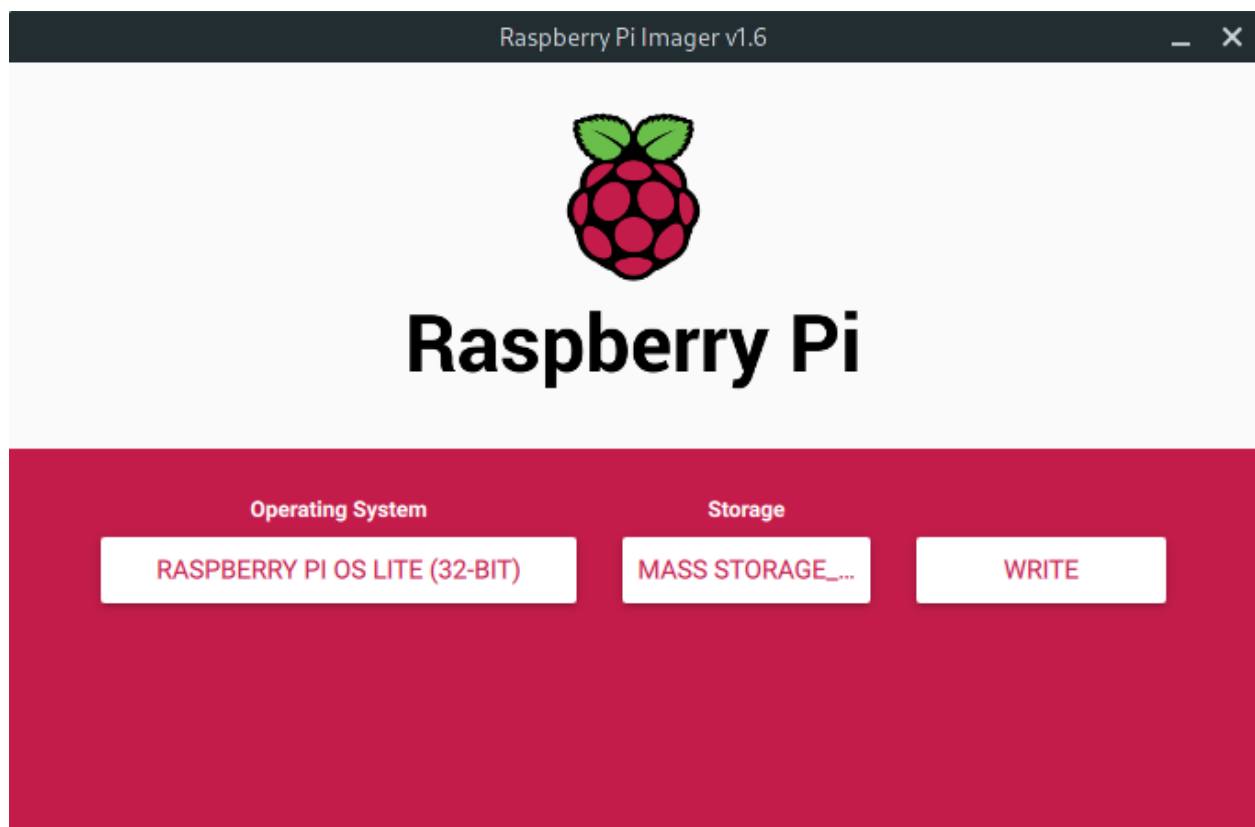
Now that you have configured the settings and selected an operating system, insert your microSD card and click the **CHOOSE STORAGE** button.



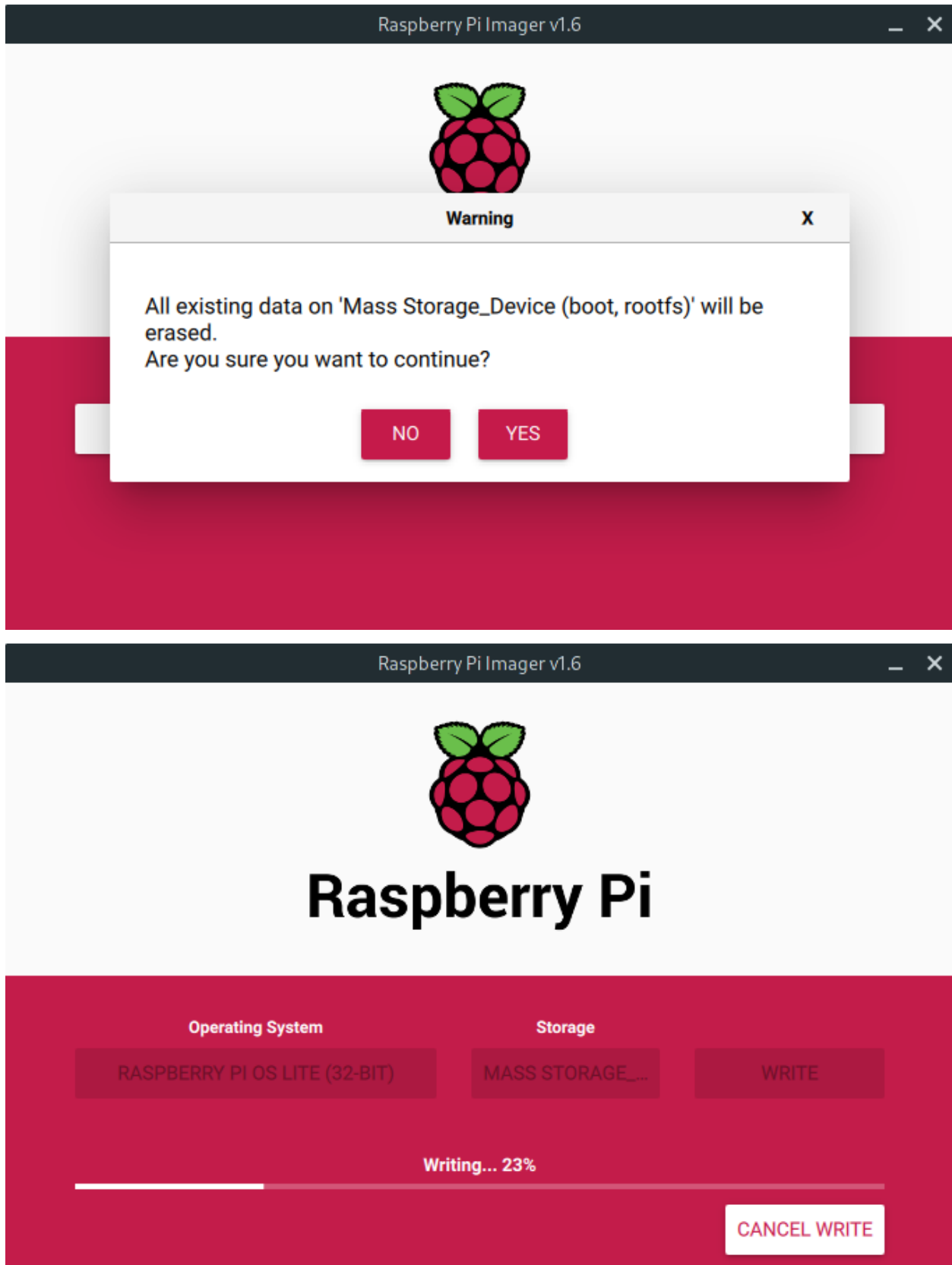
Select your microSD card from the menu.



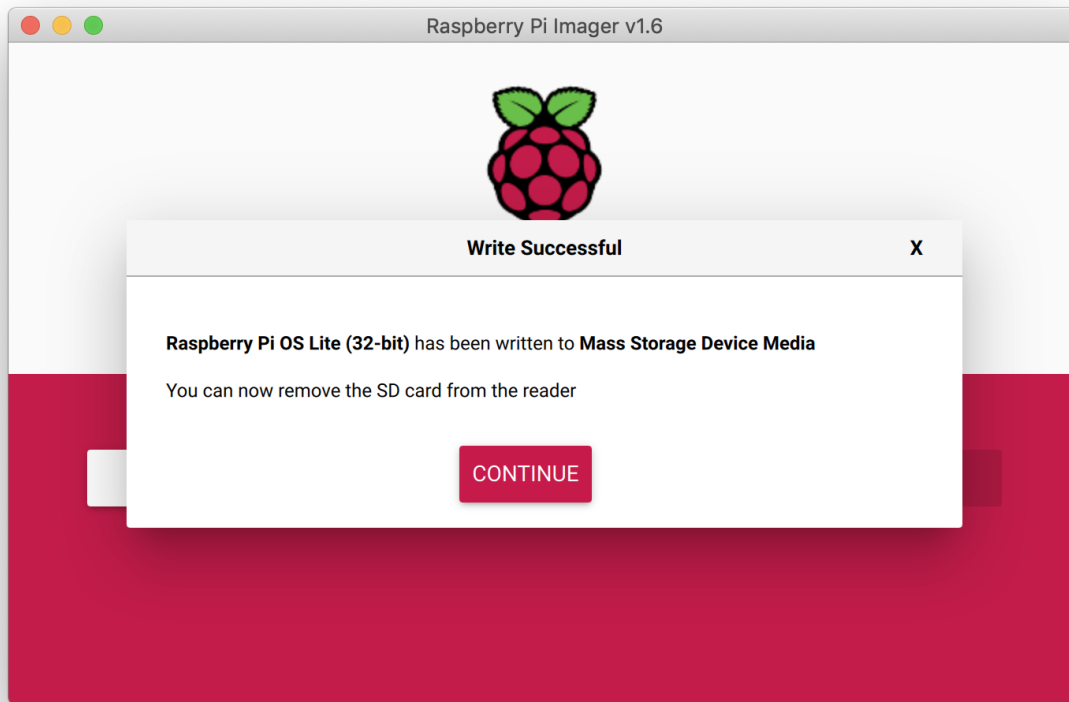
Now click the **WRITE** button to install Raspberry Pi OS Lite to your microSD card.



You will be reminded that the microSD card will be erased in the process. Click **YES** to acknowledge.



It will take a several minutes for the image to be written to your microSD card. Once it completes quit Raspberry Pi Imager and remove the microSD card.



Steps 1-3 describe the process of manually installing Raspberry Pi OS Lite and configuring SSH and Wi-Fi in case the Raspberry Pi Imager does not work for you. If you used the Raspberry Pi Imager, you can skip to [Step 4](#).

Step 1: Download Raspberry Pi OS

Before we begin installing the necessary tools to get the sentry server running on the Raspberry Pi, we need to install an operating system on the microSD card that we wish to boot the Pi from. For this tutorial, we will be using **Raspberry Pi OS Lite** since we won't require a Desktop Environment.

Open the following page in your browser and click the download button for **Raspberry Pi OS Lite**: <https://www.raspberrypi.org/software/operating-systems/>

At the time of writing [this image](#) was used.

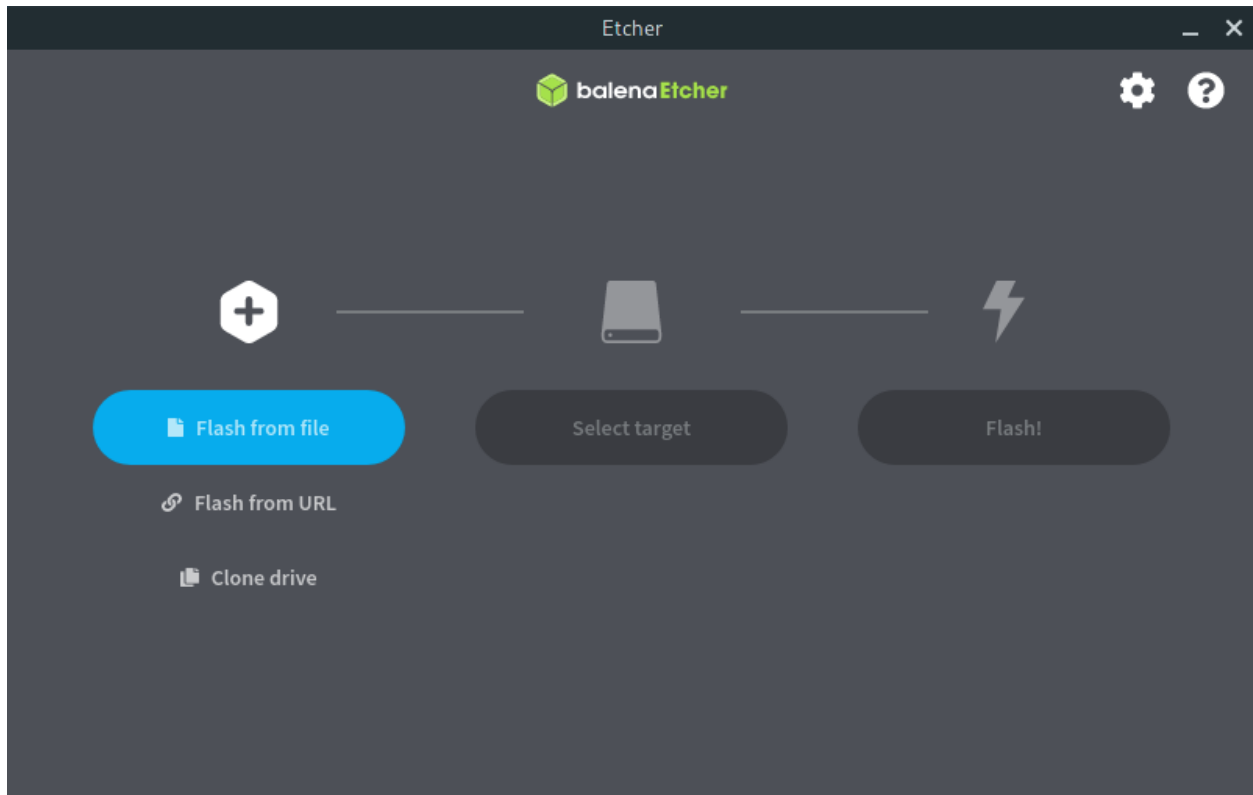
After the download of the .zip completes, extract the contents to a suitable location. You will end up with a disk image named something like 2021-01-11-raspbios-buster-armhf-lite.img.

Step 2: Install Raspberry Pi OS

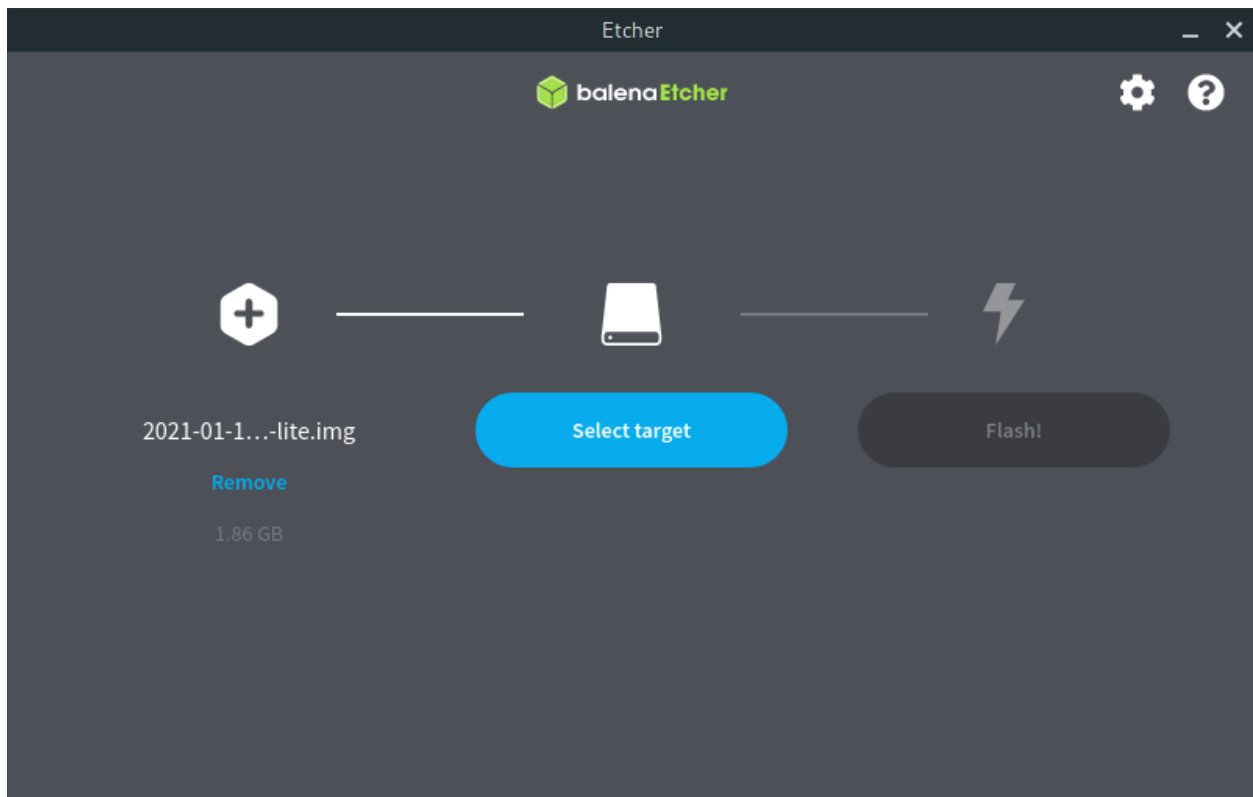
Now that we have the Raspberry Pi OS image we need to flash it to the microSD card. There are several ways of doing this, ranging from the `dd` command to numerous graphical utilities.

For this tutorial, we'll use [balena Etcher](#) because it works on Windows, Mac, and Linux, but if you have a preferred tool, please feel free to use it instead.

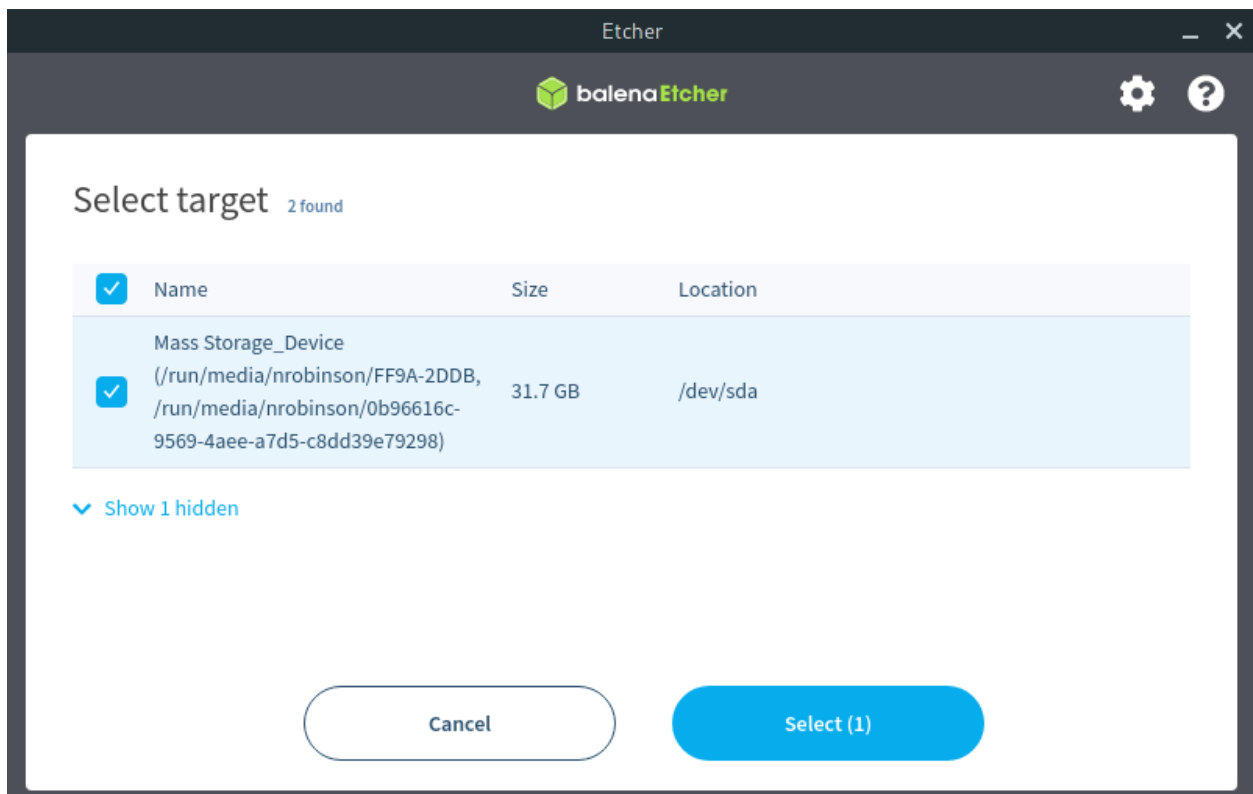
Upon opening Etcher, you will see the following window:



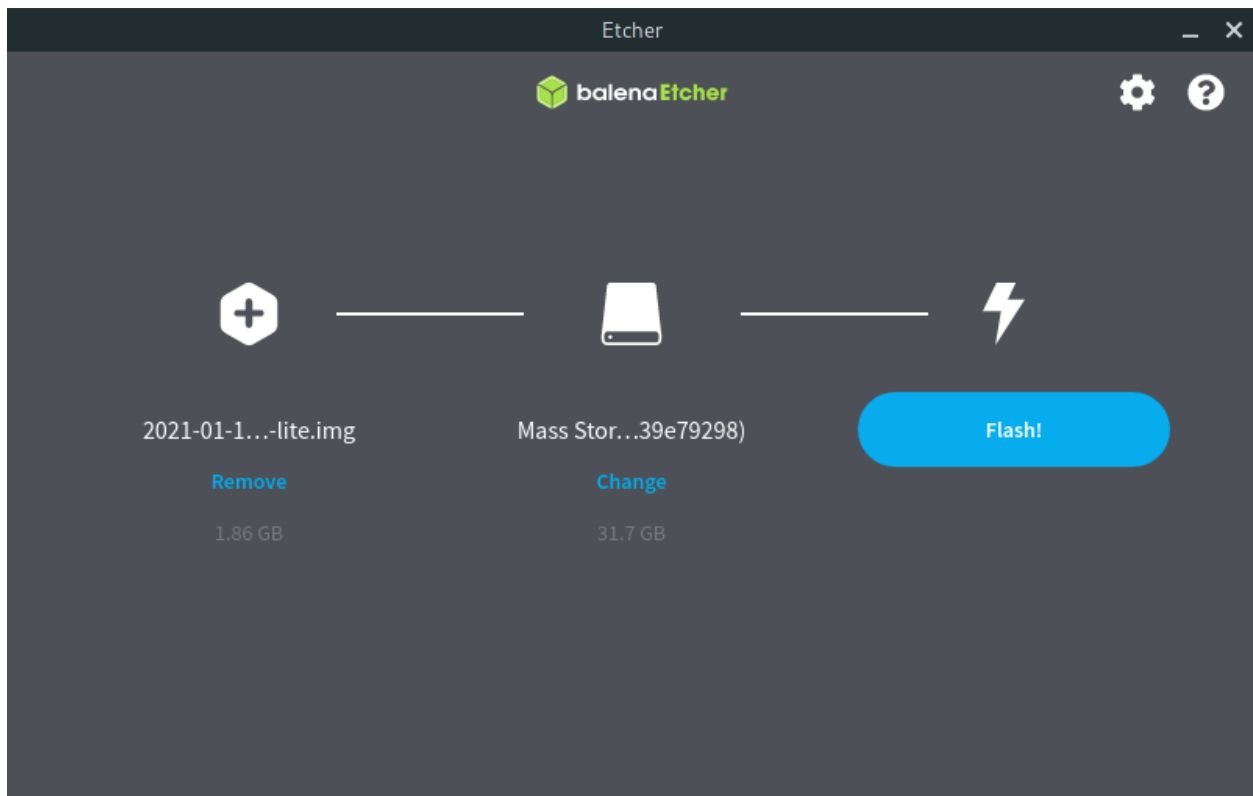
Click the **Flash from file** button and select the `.img` you extracted from the `.zip` that you downloaded.



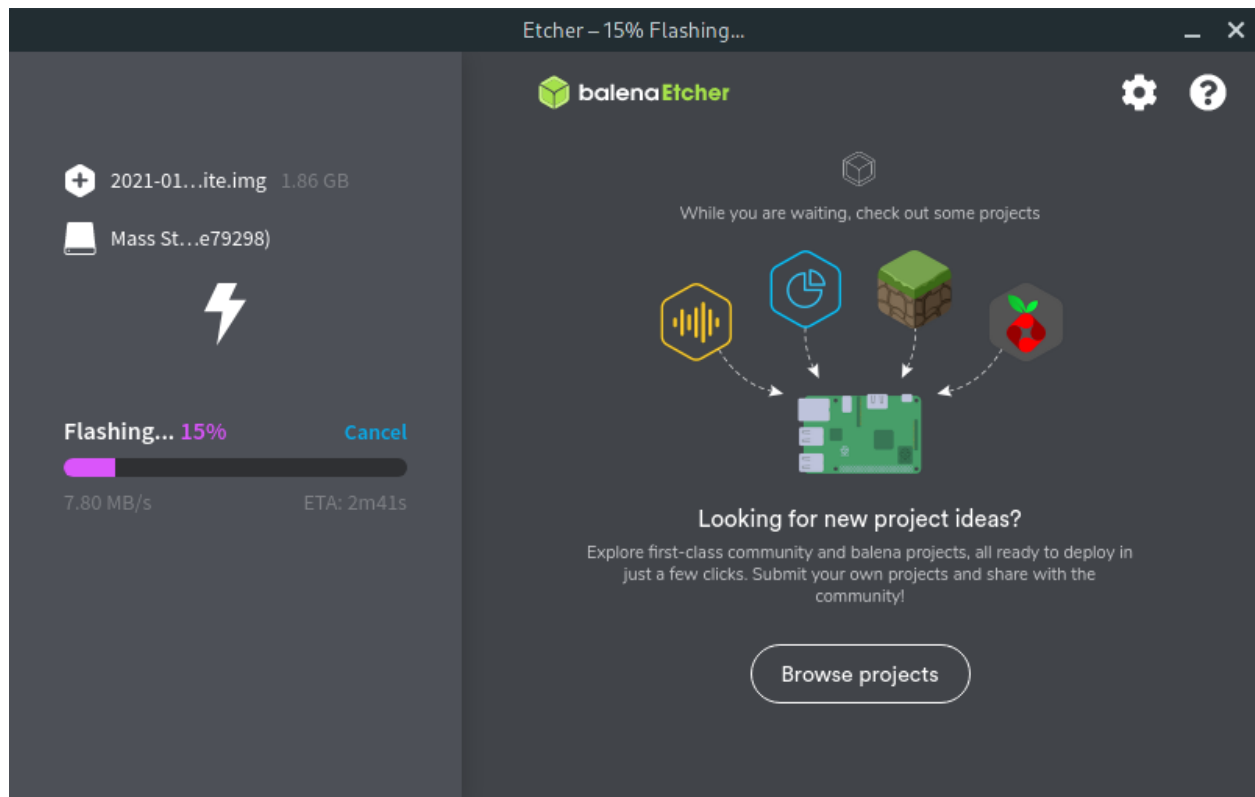
Insert your microSD card into the reader and connect the reader to your computer. Next, click the **Select target** button.



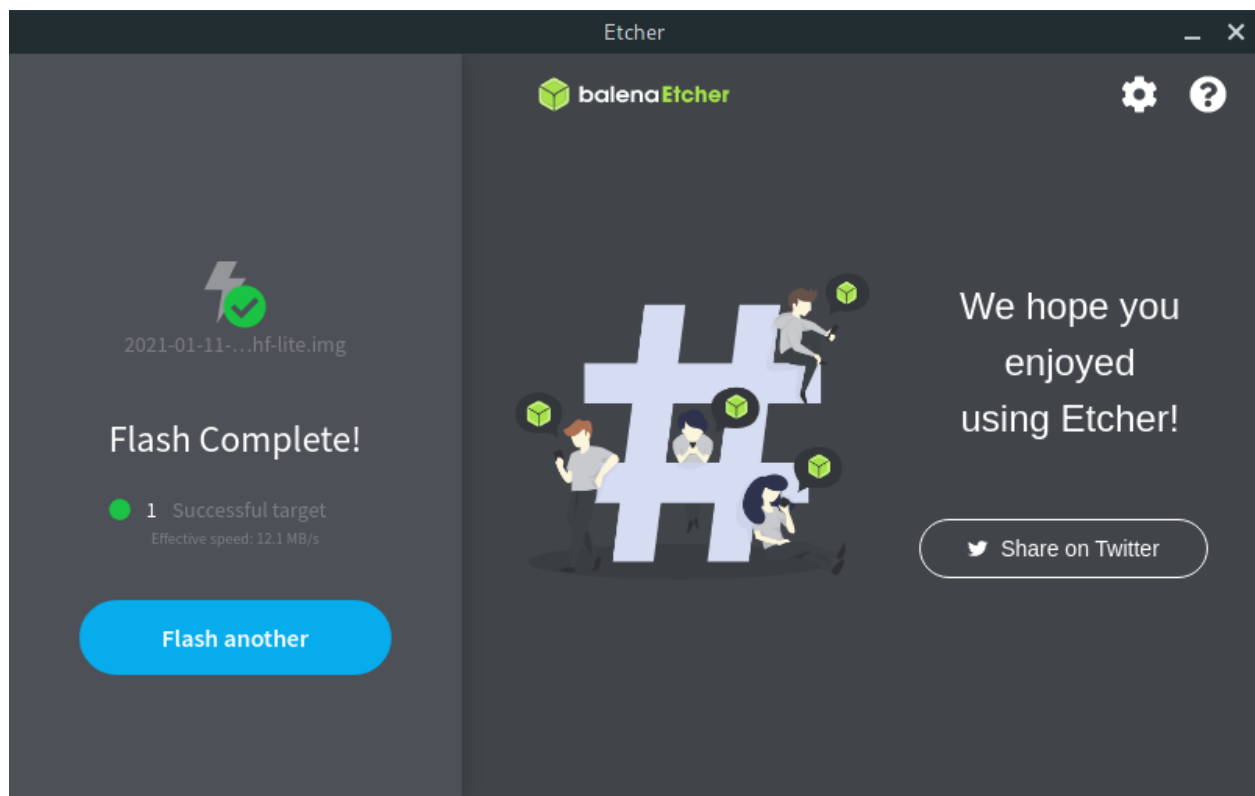
Select the drive that is your microSD card. Do not select any other drives!



Now that you have selected the image and the drive, click the **Flash!** button to flash the Raspberry Pi OS image to your microSD card.



It will take a few minutes for Etcher to flash and validate the image.



You can quit Etcher after it finishes flashing the image.

Step 3: Headless mode customizations

When using the Raspberry Pi you can choose to connect a mouse, keyboard, and HDMI display, but for this tutorial we will use the Raspberry Pi in headless mode, logging in remotely with SSH to control the Pi.

Step 3a: Enable SSH

To enable SSH on the Raspberry Pi when it boots, we must create an empty text file named `ssh` on the boot partition of the microSD card.

- Open the `boot` partition of the microSD card in your file manager.
- Create an empty file named `ssh`.

Step 3b: Enable Wi-Fi (Optional)

Next, we will enable Wi-Fi on the Raspberry Pi. If you will be using Ethernet you can skip this step.

To enable Wi-Fi we must create another text file on the boot partition:

- Open the `boot` partition of the microSD card in your file manager.
- Create a text file called `wpa_supplicant.conf`.
- In `wpa_supplicant.conf` paste in the following configuration:

```
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1
country=US
```

```
network={
    ssid="YOUR_SSID"
    psk="YOUR_PASSWORD"
}
```

- Change `YOUR_SSID` and `YOUR_PASSWORD` to the SSID and password of your Wi-Fi network.

Step 4: Boot and connect to the Raspberry Pi

Now that we have installed the OS and enabled SSH and Wi-Fi, it's time to power on and connect to the Pi.

- Ensure that the Raspberry Pi camera is properly connected using the ribbon cable.
- Insert the microSD card, and connect Ethernet and a monitor if you wish.
- Connect the USB-C power cable to the Pi.

The Pi should begin booting. You'll see some red and green flashes from the onboard LEDs and lots of text fly if you've attached a monitor.

Step 4a: Finding the IP address

It can be a challenge to find the IP address of your Raspberry Pi.

Luckily there are a few ways to do this:

- The first is to boot the Pi with a monitor attached. Towards the end of the boot process, a line starting with `My IP address is` will be printed, listing the IPv4 and IPv6 addresses of the Pi.

```
Starting Bluetooth service...
Starting Load/Save RF Kill Switch Status...
[ OK ] Started Load/Save RF Kill Switch Status.
[ OK ] Started Bluetooth service.
[ OK ] Reached target Bluetooth.
[ OK ] Started Raspberry Pi bluetooth helper.
Starting Hostname Service...
[ OK ] Started dhcpcd on all interfaces.
[ OK ] Reached target Network.
Starting Permit User Sessions...
Starting OpenBSD Secure Shell server...
Starting /etc/rc.local Compatibility...
[ OK ] Started Permit User Sessions.
My IP address is 192.168.1.16 ::75d5:46d7:b846:e496 ::375f:d08:14d5:5f43
[ OK ] Started /etc/rc.local Compatibility.
[ OK ] Started Getty on tty1.
[ OK ] Reached target Login Prompts.
[ OK ] Started Hostname Service.
[ OK ] Started OpenBSD Secure Shell server.
[ OK ] Started Turn on SSH if /boot/ssh is present.

Raspbian GNU/Linux 10 raspberrypi tty1

[ OK ] Reached target Multi-User System.
[ OK ] Reached target Graphical Interface.
Starting Update UTMP about System Runlevel Changes...
[ OK ] Started LSB: Resize the root filesystem to fill partition.
[ OK ] Started Update UTMP about System Runlevel Changes.

-
```

On my Raspberry Pi the line begins with:

My IP address is 192.168.1.16

- The second way is to take advantage of the `raspberrypi.local` mDNS hostname the Pi provides. In most circumstances, if there is only one Raspberry Pi on your network, `raspberrypi.local` should resolve to your Pi in SSH, HTTP, and other protocols. If you set a different hostname using Raspberry Pi Imager use it instead of `raspberrypi.local` for the rest of this tutorial.

A more advanced way to find the IP address would be to use [arp-scan](#), a powerful command-line tool for Linux and macOS that allows you to discover devices on your network and identify the manufacturer based on the MAC address. The following command uses `arp-scan` to discover devices on your local network and filter the results with `grep`.

```
$ sudo arp-scan -l | grep 'Raspberry Pi'

192.168.1.7      b8:27:eb:57:9b:58  Raspberry Pi Foundation
192.168.1.7      b8:27:eb:57:9b:58  Raspberry Pi Foundation (DUP: 2)
192.168.1.48     dc:a6:32:01:04:d4  Raspberry Pi Trading Ltd
192.168.1.48     dc:a6:32:01:04:d4  Raspberry Pi Trading Ltd (DUP: 2)
192.168.1.16     dc:a6:32:01:04:d3  Raspberry Pi Trading Ltd
192.168.1.38     b8:27:eb:59:20:f3  Raspberry Pi Foundation
192.168.1.48     dc:a6:32:01:04:d3  Raspberry Pi Trading Ltd (DUP: 3)
```

Newer Raspberry Pi's will be identified as Raspberry Pi Trading Ltd, while older Pi's will be identified as Raspberry Pi Foundation.

Step 4b: Connecting with SSH

Now that the Raspberry Pi is connected to our network and we know the IP address and enabled the SSH server, we'll remotely log into the Pi using SSH to further configure the Pi and set up the webcam server.

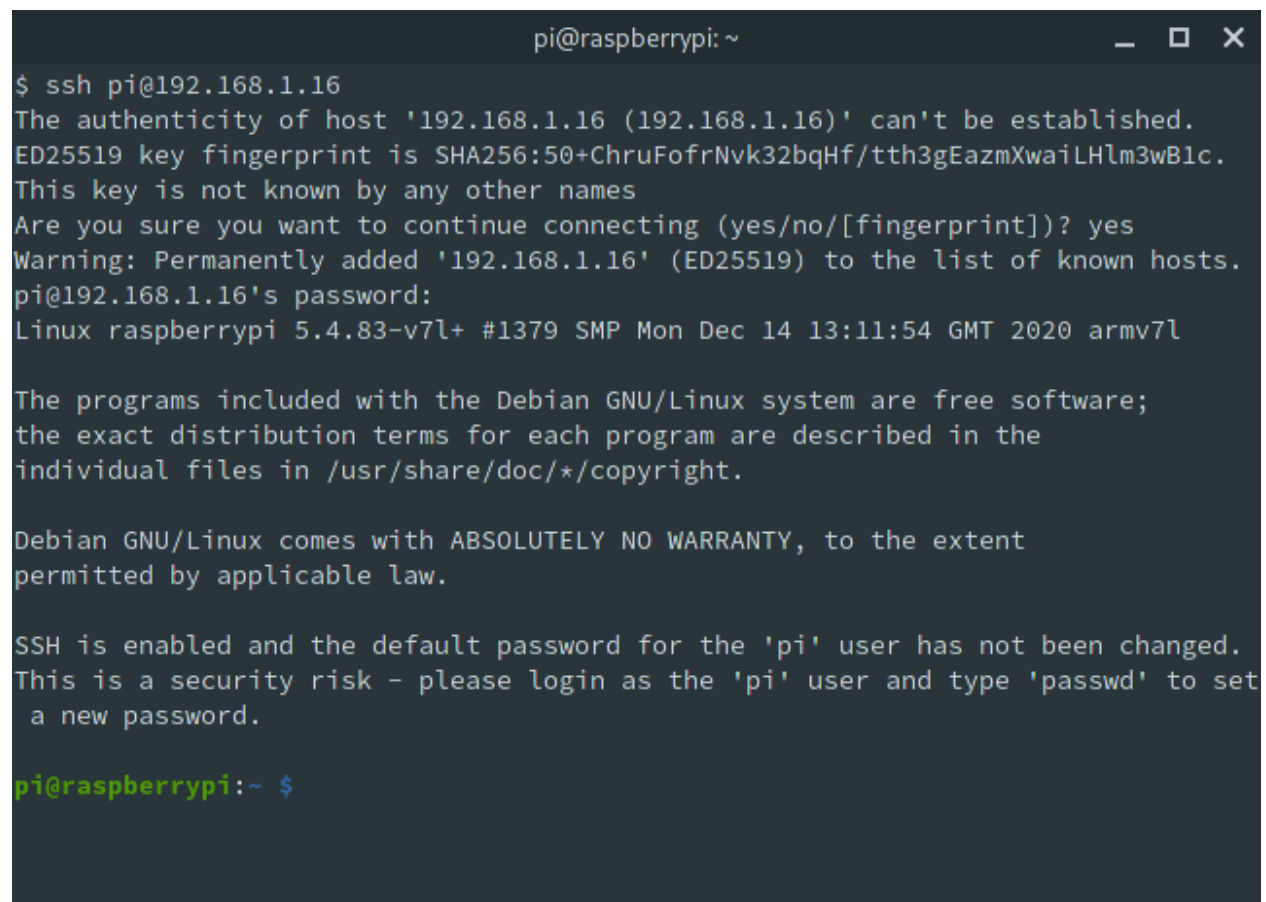
On Linux, macOS, and Windows, the `ssh` command is available in your terminal emulator.

- On Windows open either command prompt or Powershell.
- On macOS open Terminal.app
- On Linux you probably already know how to open your preferred terminal emulator.

Enter the following to connect to your Pi using SSH:

```
ssh pi@raspberrypi.local
```

- You will likely be prompted to accept the fingerprint of the host. Enter **yes** to continue connecting.
- When asked for the password of the `pi` user, enter the default password of **raspberry** and press Enter. (As you type the password the characters will not be printed to the terminal.)



```
pi@raspberrypi: ~
$ ssh pi@192.168.1.16
The authenticity of host '192.168.1.16 (192.168.1.16)' can't be established.
ED25519 key fingerprint is SHA256:50+ChruFofrNvk32bqHf/tth3gEazmXwaiLHlm3wB1c.
This key is not known by any other names
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added '192.168.1.16' (ED25519) to the list of known hosts.
pi@192.168.1.16's password:
Linux raspberrypi 5.4.83-v7l+ #1379 SMP Mon Dec 14 13:11:54 GMT 2020 armv7l

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.

SSH is enabled and the default password for the 'pi' user has not been changed.
This is a security risk - please login as the 'pi' user and type 'passwd' to set
a new password.

pi@raspberrypi:~ $
```

If `raspberrypi.local` isn't working, use the IP address you obtained in Step 4a.

In my case: `ssh pi@192.168.1.16`

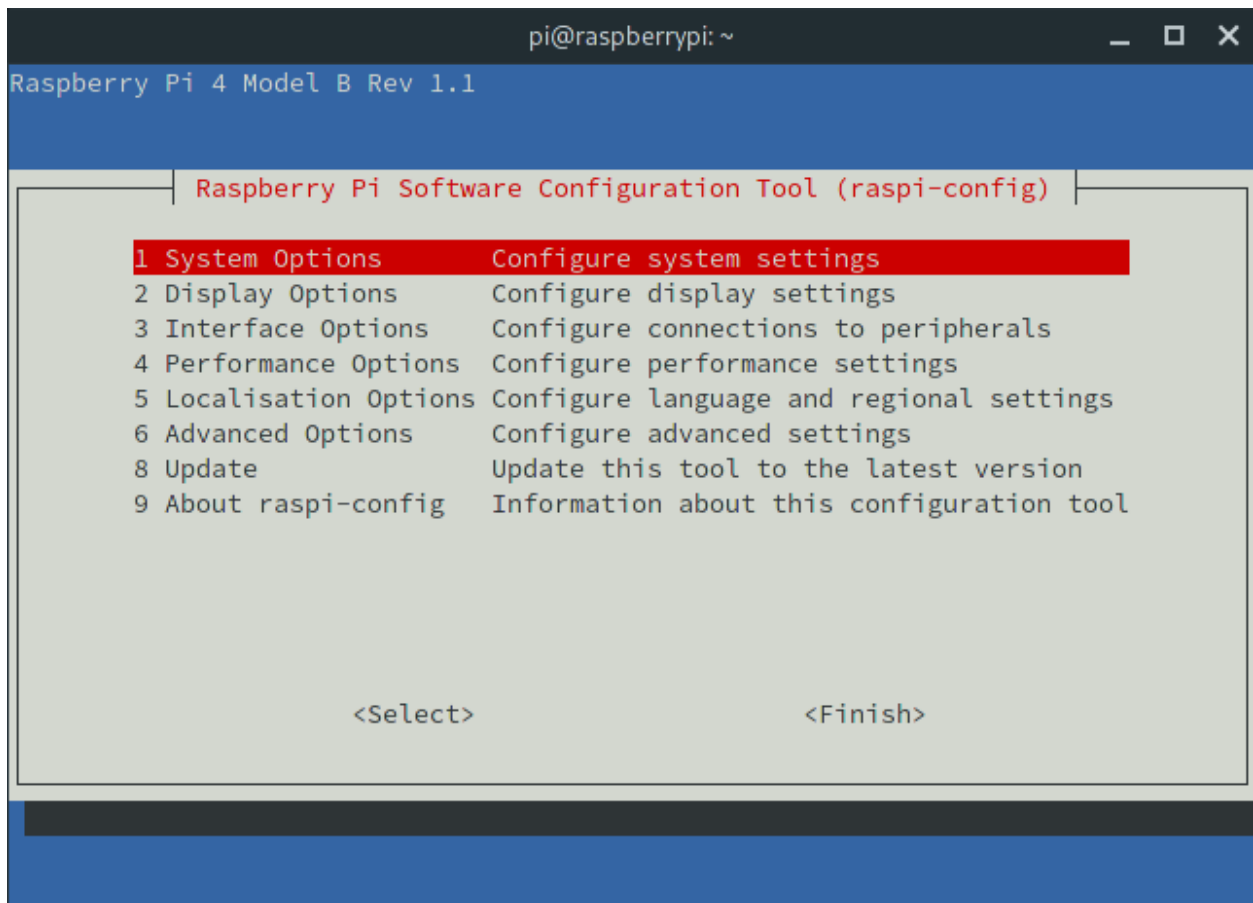
Step 5: Configure the Raspberry Pi and enable the camera

Now that we have the Pi up and running it's time to begin using it. We first need to configure some system settings and enable the Raspberry Pi camera.

Enter the following to open the configuration tool:


```
sudo raspi-config
```

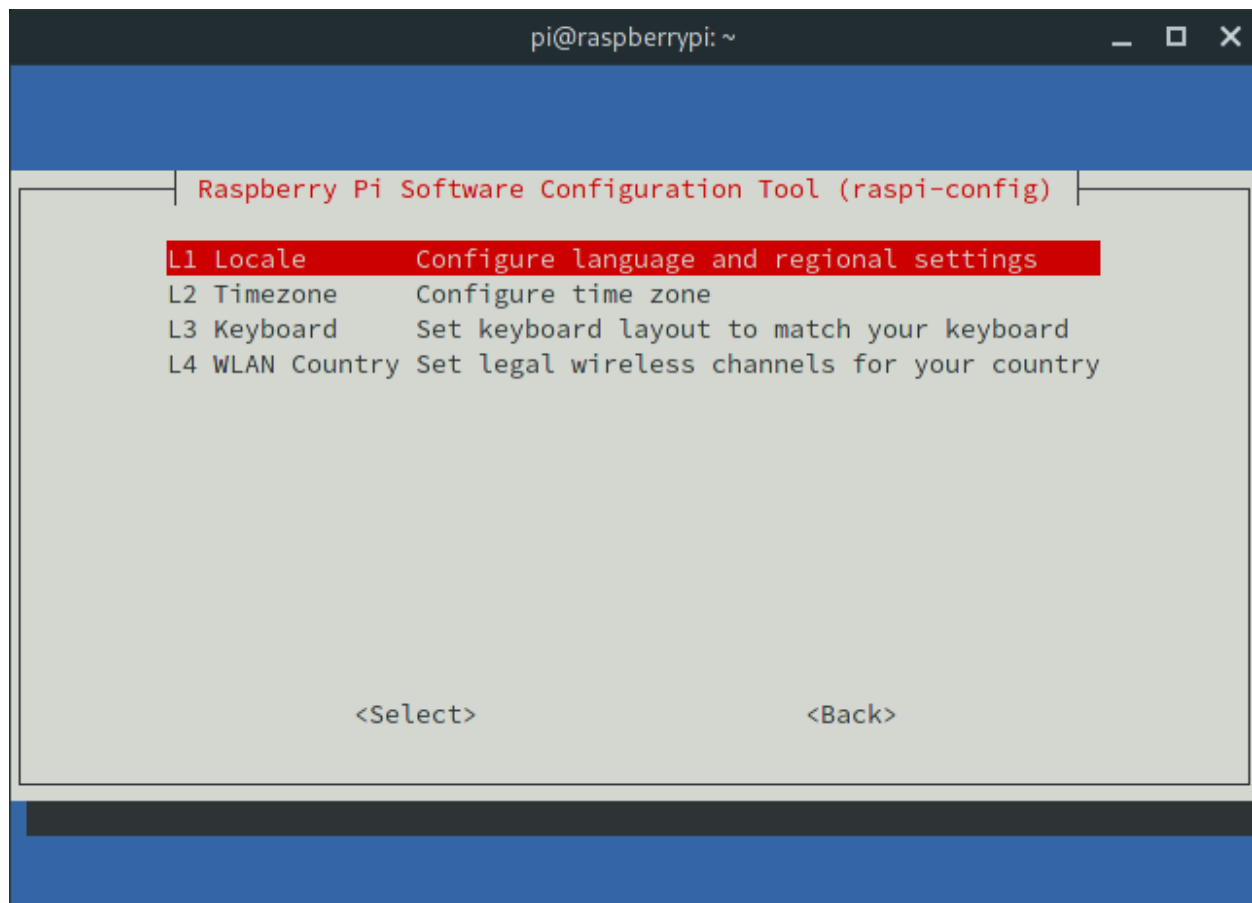
You will be presented with the following menu:



If you used Raspberry Pi Imager to set locale, timezone, and password, skip to [Enabling I2C support](#).

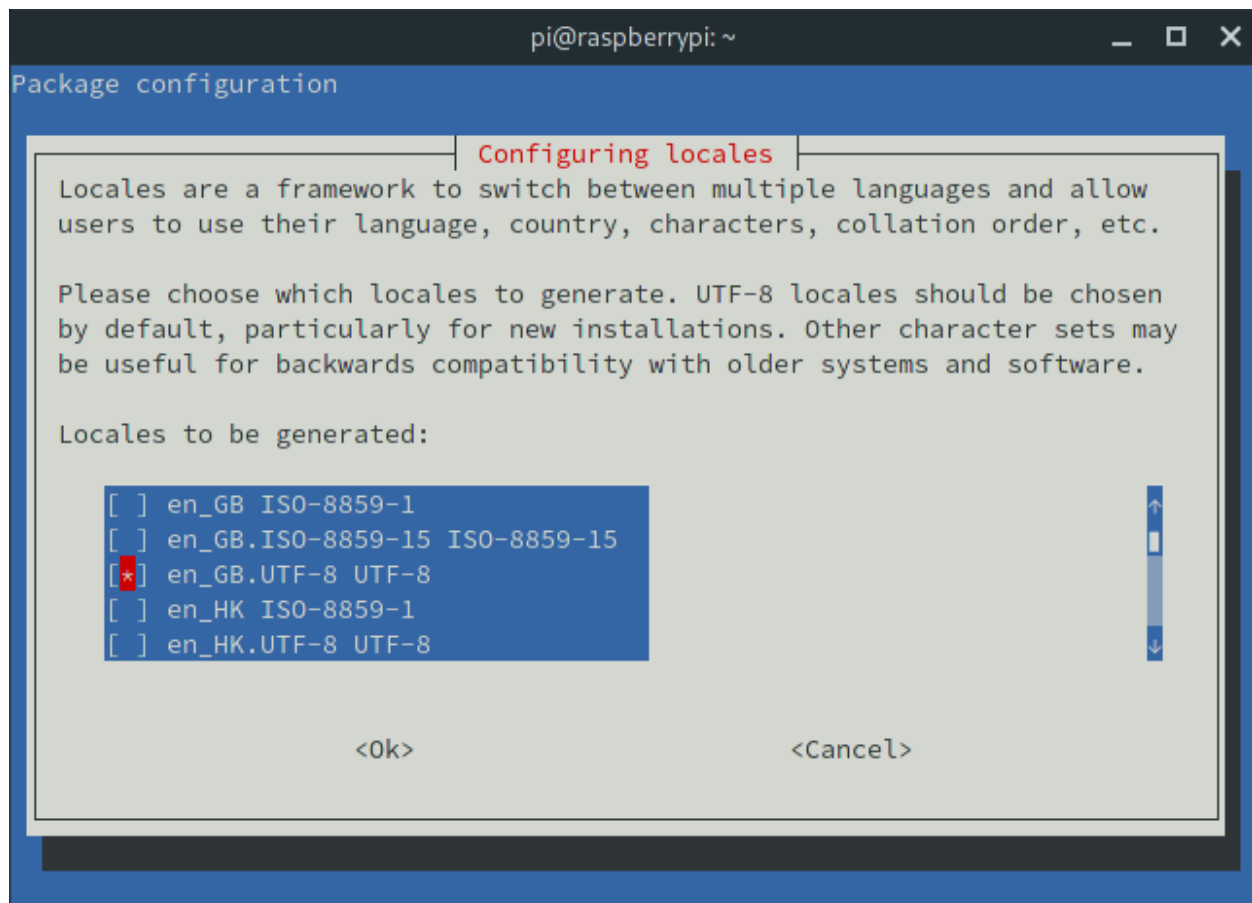
Changing Locale

Using the arrow keys, navigate down to **Localisation Options** and press Enter:

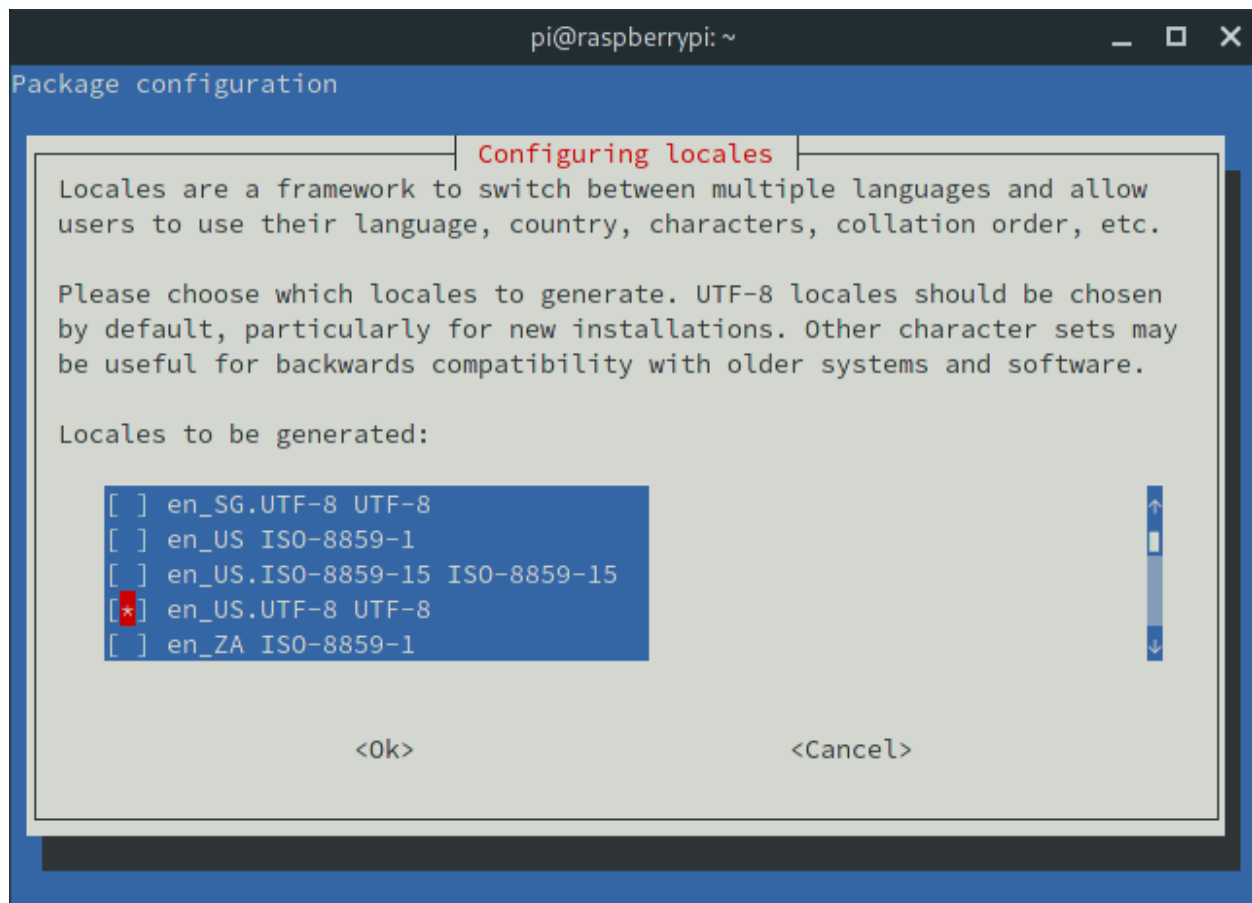


Select **Locale** and press Enter.

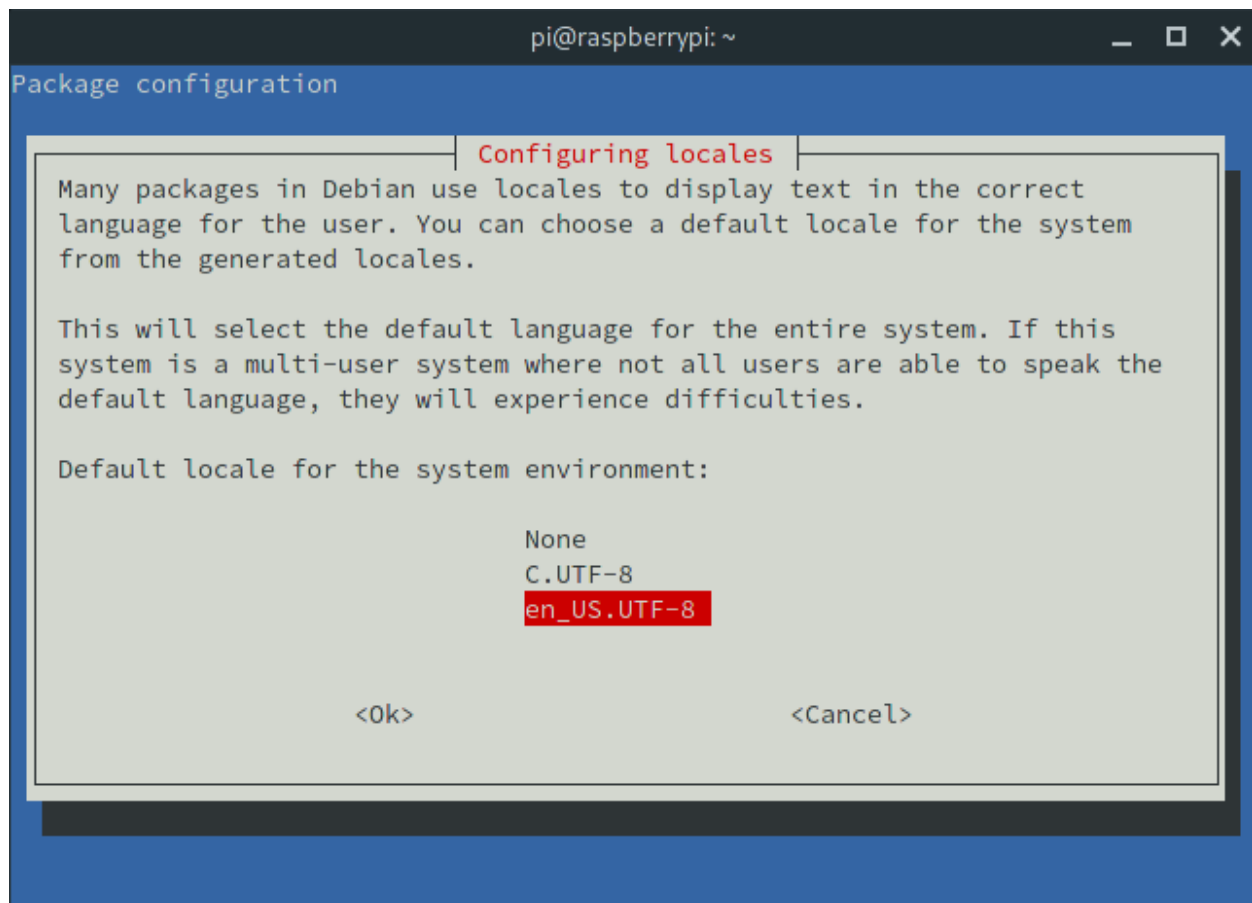
Navigate down to the **en_GB.UTF-8 UTF-8** option and press Space to disable it:



Navigate down to the `en_US.UTF-8 UTF-8` option and press Space to enable it:



Press Enter to apply the locale.

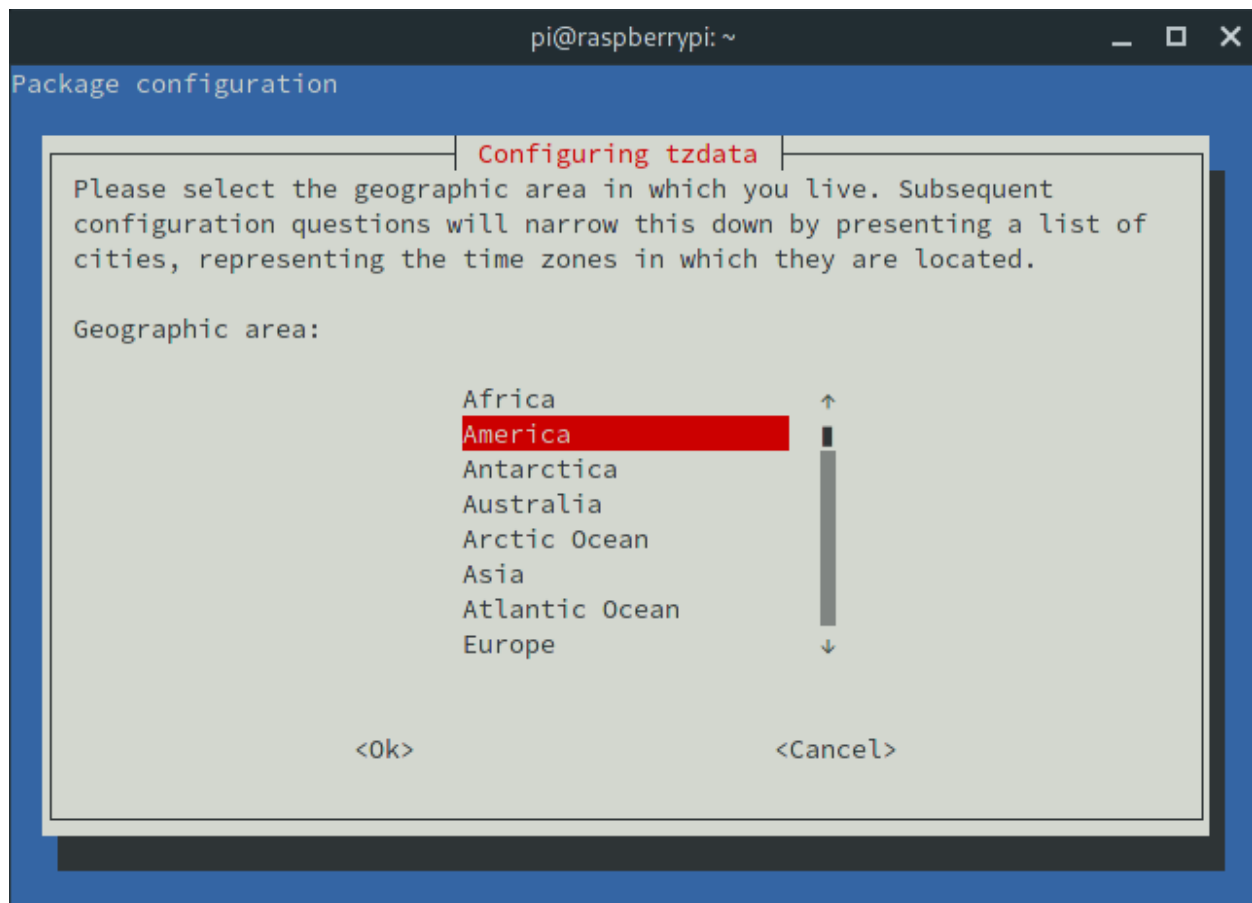


Select `en_US.UTF-8` as the default locale and press Enter.

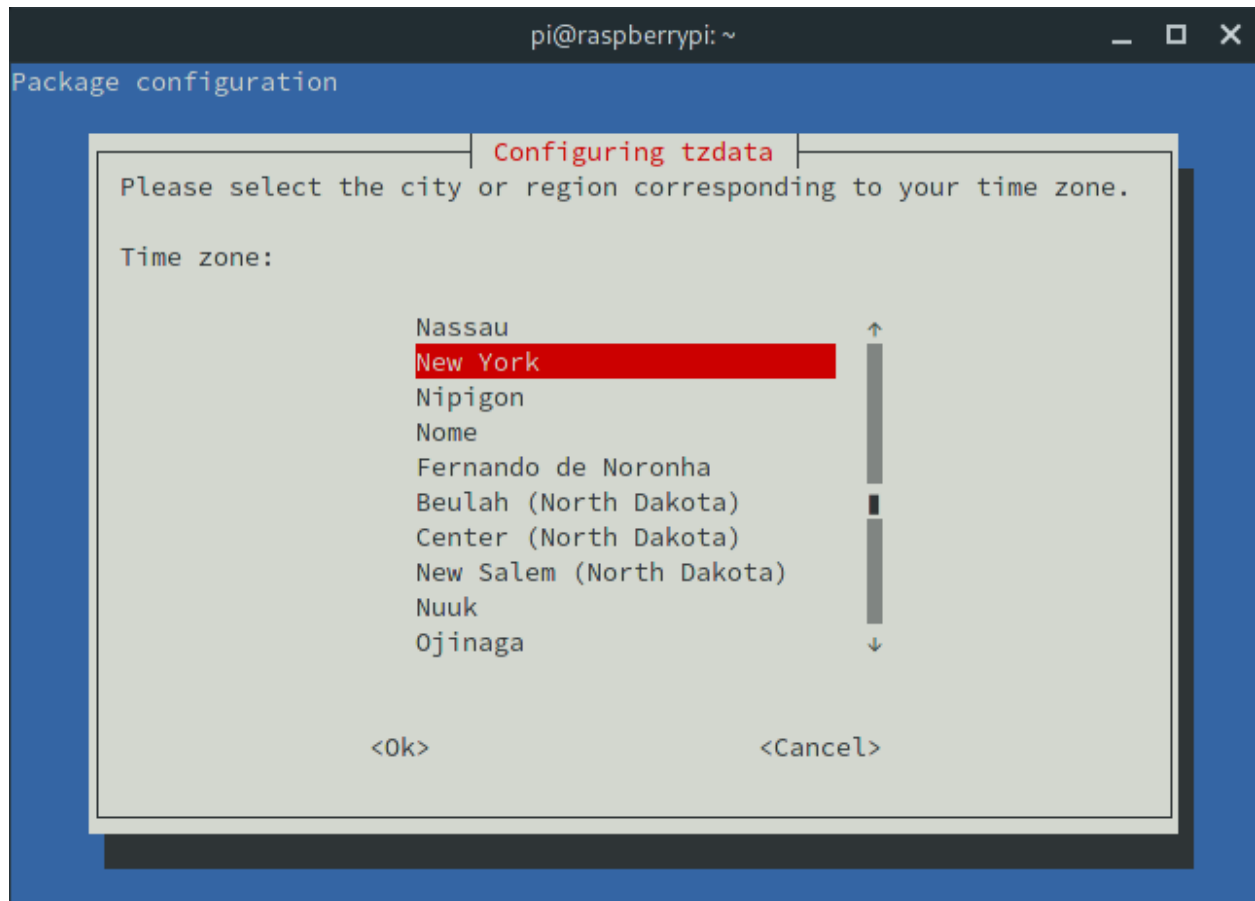
After the locale is generated, you will be brought back to the initial menu.

Changing Timezone

Select `Localisation Options` again, and choose the `Timezone` option:

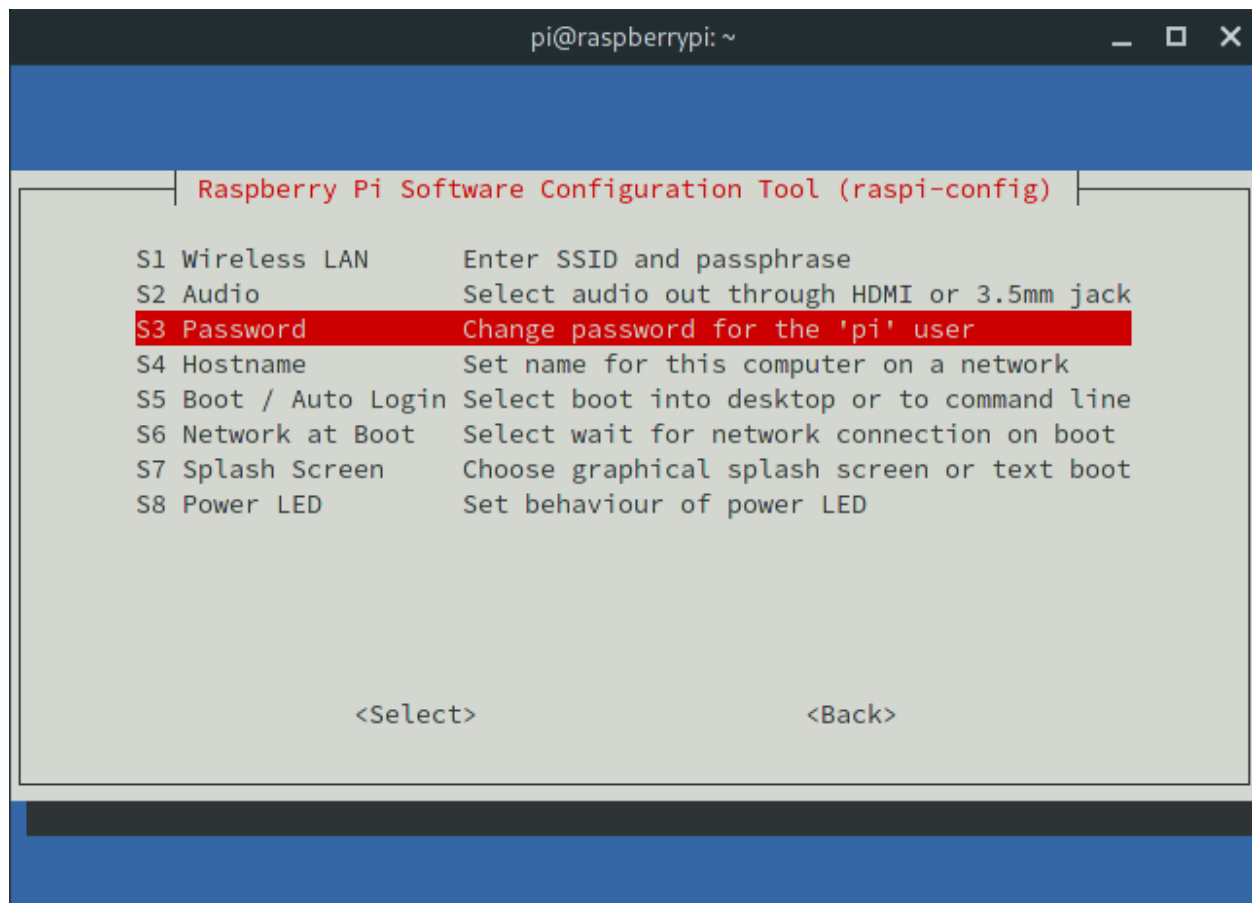


My timezone is America/New York so that is what I selected.



Changing the password

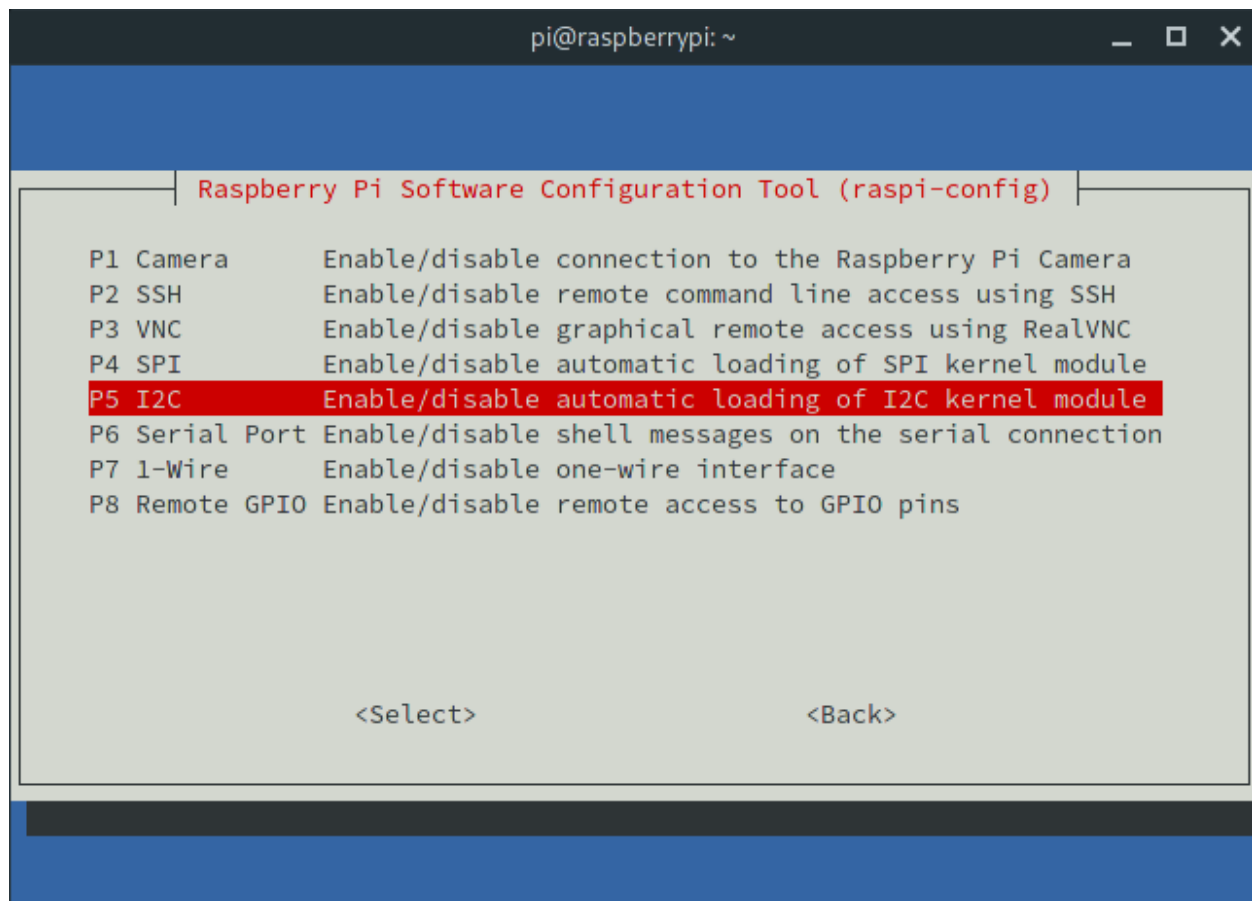
Under **System Options** select the **Password** option:



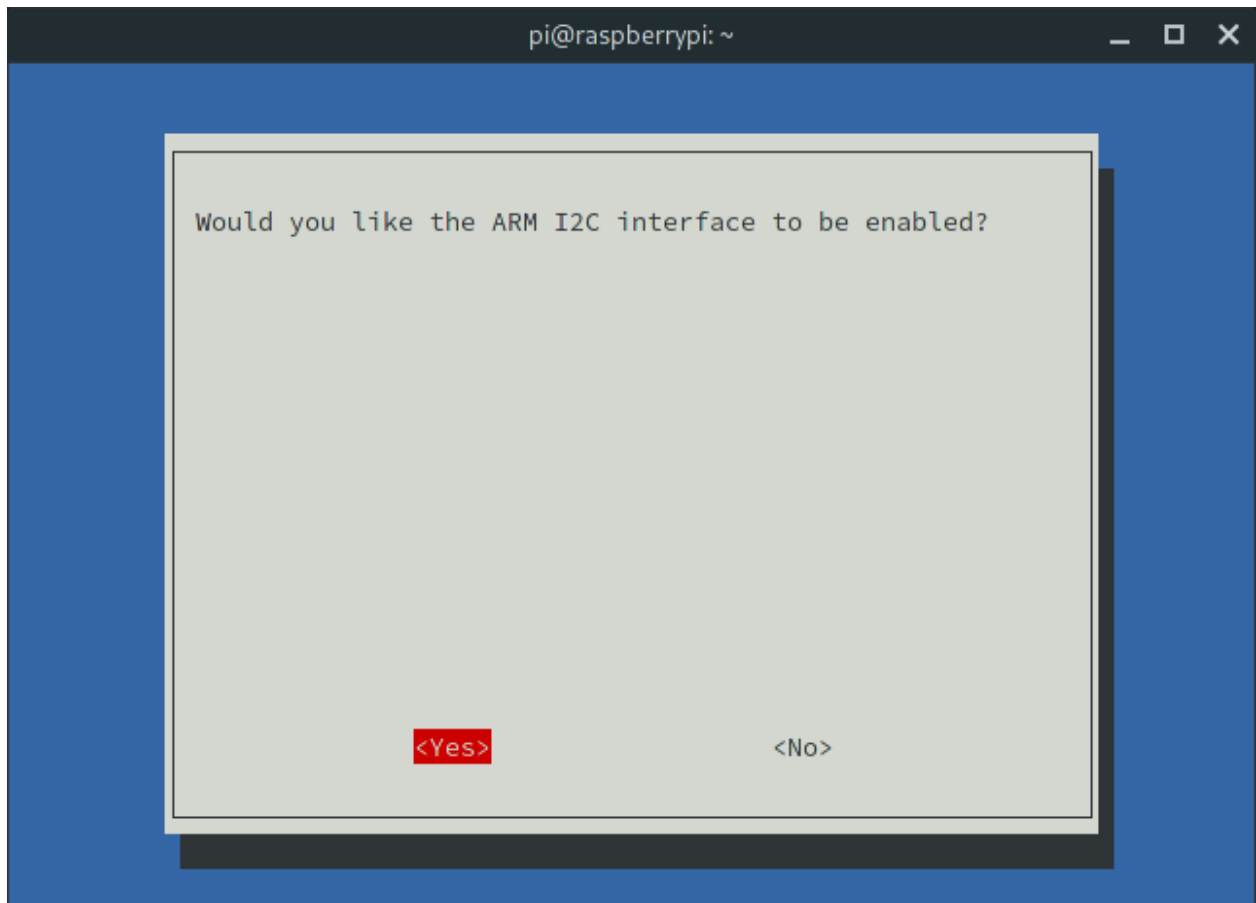
You will be prompted to enter and confirm a new password.

Enabling I2C support

Under **Interface Options** select the I2C option:

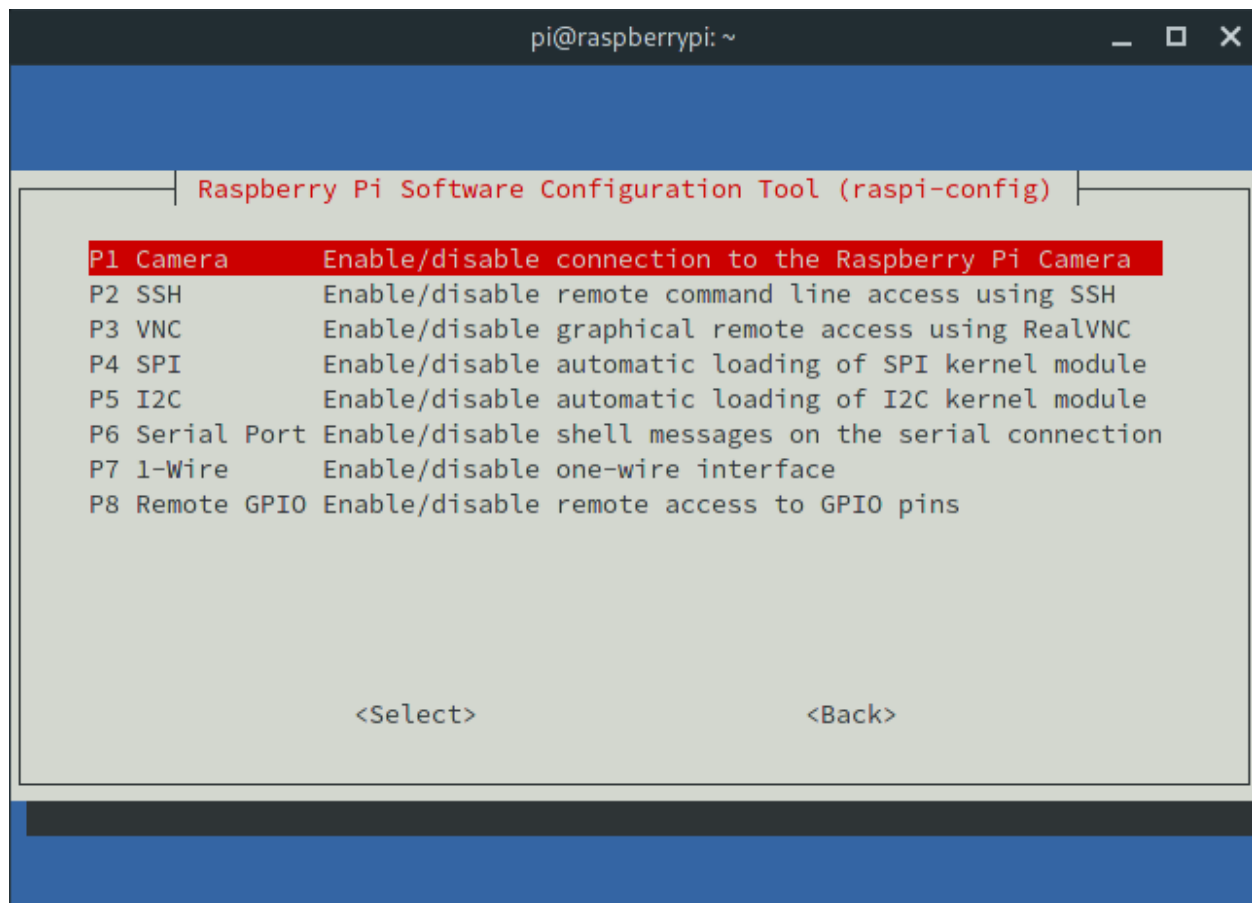


Select **Yes** to enable I2C.

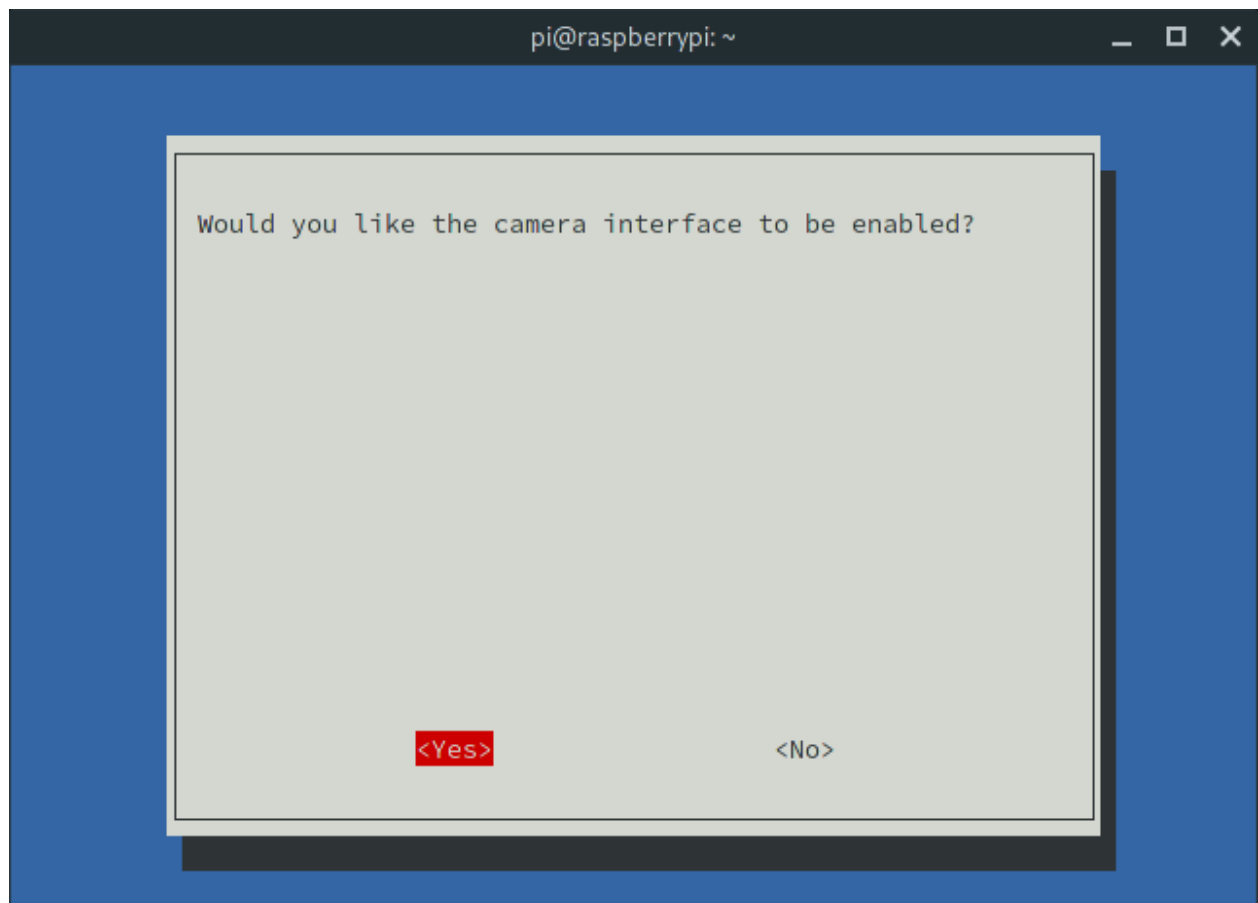


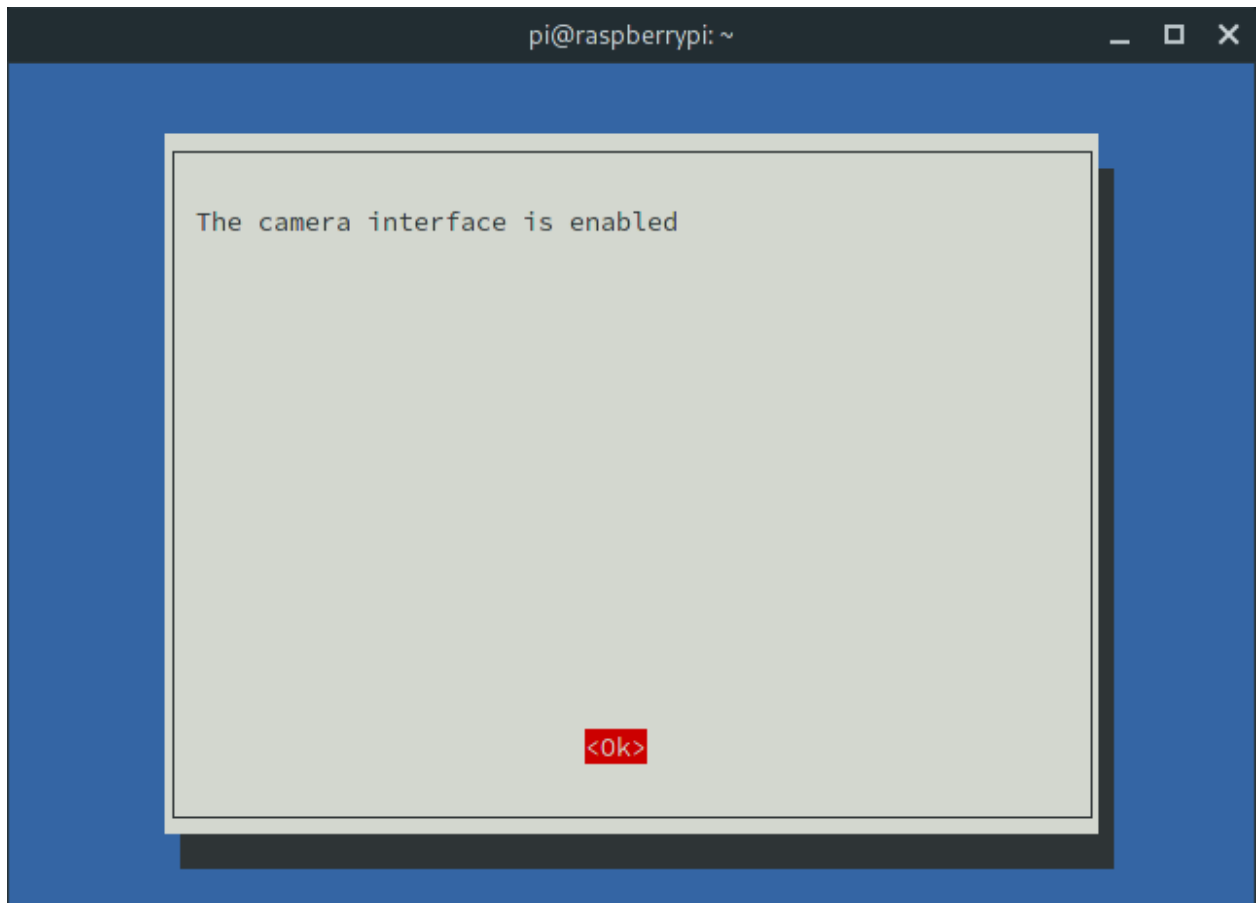
Enabling the camera

Under Interface Options select the Camera option:

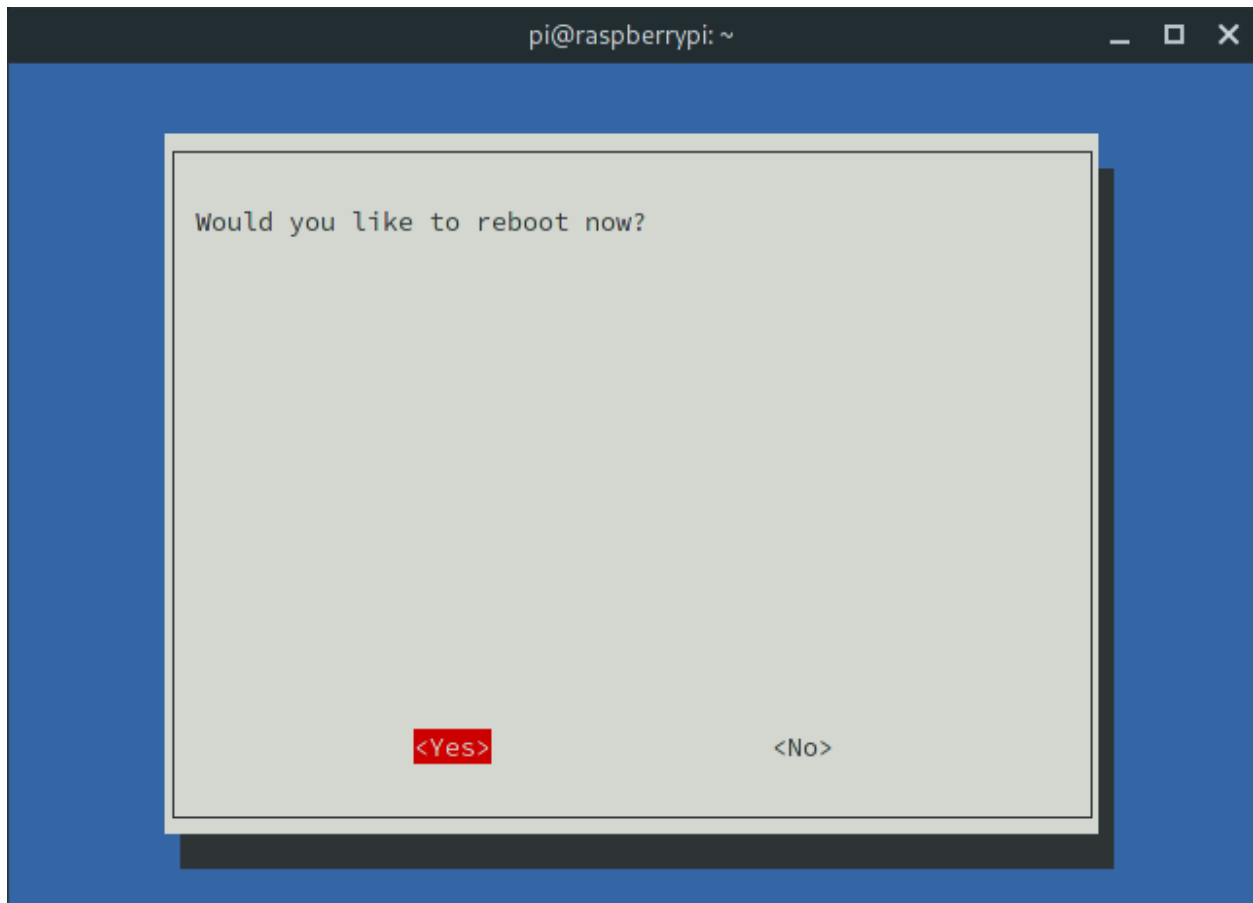


Select **Yes** to enable the camera.





After changing the locale, timezone, password, and enabling the camera, select **Finish** in the menu. When asked to reboot select **No**.



Step 6: Install updates

Now that we have configured the Raspberry Pi and enabled the camera, it's time to install the necessary packages to provide the camera server.

Install any available updates with the following:

```
sudo apt update && sudo apt upgrade
```

When asked to continue enter `y`:

```
pi@raspberrypi: ~
Fetched 13.5 MB in 7s (1,827 kB/s)
Reading package lists... Done
Building dependency tree
Reading state information... Done
53 packages can be upgraded. Run 'apt list --upgradable' to see them.
Reading package lists... Done
Building dependency tree
Reading state information... Done
Calculating upgrade... Done
The following packages will be upgraded:
  alsa-utils base-files bind9-host bluez-firmware ca-certificates
  device-tree-compiler file firmware-atheros firmware-brcm80211
  firmware-libertas firmware-misc-nonfree firmware-realtek iproute2
  libbind9-161 libdns-export1104 libdns1104 libgnutls30 libisc-export1100
  libisc1100 libisccc161 libisccfg163 libldap-2.4-2 libldap-common liblwres161
  libmagic-mgc libmagic1 libpam-systemd libraspberrypi-bin libraspberrypi-dev
  libraspberrypi-doc libraspberrypi0 libssl1.1 libsystemd0 libudev1 libzstd1
  openssh-client openssh-server openssh-sftp-server openssl python-rpi.gpio
  raspberrypi-bootloader raspberrypi-kernel raspberrypi-sys-mods raspi-config
  rpi-eeprom rpi.gpio-common ssh sudo systemd systemd-sysv tzdata udev unzip
53 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
Need to get 151 MB of archives.
After this operation, 7,435 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
```

It will take a few minutes for the updates to download and apply. Reboot after the updates finish.

```
sudo reboot
```

Step 7: Installing UV4L

Log back into the Pi over SSH using the new password you created.

Accept the repo signing key:

```
curl https://www.linux-projects.org/listing/uv4l_repo/lpkey.asc | sudo apt-key add -
```

Add the repo to your apt sources:

```
echo "deb https://www.linux-projects.org/listing/uv4l_repo/raspbian/stretch stretch main" \
| sudo tee -a /etc/apt/sources.list
```

Install the packages:

```
sudo apt update
sudo apt install uv4l uv4l-raspicam uv4l-raspicam-extras uv4l-webrtc
```

Reducing resolution and framerate

By default, UV4L streams at 1920x1080 30FPS, which is an incredibly high data rate.

Edit the UV4L configuration file:

```
sudo nano /etc/uv4l/uv4l-raspicam.conf
```

Go down to the raspicam driver options section:

```
#####  
# raspicam driver options  
#####
```

```
encoding = mjpeg  
# width = 640  
# height = 480  
framerate = 30  
#custom-sensor-config = 2
```

Change the the width, height and framerate values to something more reasonable:

```
width = 1280  
height = 720  
framerate = 20
```

Changing the port

Next, go down to the streaming server options section:

```
#####  
# streaming server options  
#####
```

```
### path to a separate config file that will be parsed by the streaming server  
### module directly when it's loaded,  
### in which you are allowed to specify all the streaming server options  
### listed below in the short form "option=value" instead of the longer  
### "--server-option = --option=value" form that you must use  
### in this configuration file.  
#server-config-file = #path
```

```
# server-option = --port=8080  
# server-option = --bind-host-address=localhost  
# server-option = --md5-passwords=no  
# server-option = --user-password=myp4ssw0rd  
# server-option = --admin-password=myp4ssw0rd  
### To enable 'config' user authentication  
# server-option = --config-password=myp4ssw0rd
```

Uncomment the server-option = --port line and change the port to 80:

```
server-option = --port=80
```

To save and close the editor press: Ctrl-X to Exit, Y to save changes, and Enter to confirm.

Reloading the server

Reload the UV4L server with the following:

```
sudo systemctl restart uv4l_raspicam.service
```

Verifying the stream is working

In your preferred browser open the following URL:

```
http://raspberrypi.local/stream/video.mjpeg
```


You should see the live feed from your Raspberry Pi camera!

Flipping the camera feed

Depending on how you positioned the camera, you may need to flip the video orientation:

Open the UV4L configuration file again:

```
sudo nano /etc/uv4l/uv4l-raspicam.conf
```

Go down to the `image settings options` section:

```
### image settings options:
# sharpness = 0
# contrast = 0
# brightness = 50
# saturation = 0
# iso = 400
# vstab = yes
# ev = 0
# exposure = auto
# flicker = off
# awb = auto
# imgfx = none
# metering = average
# rotation = 0
# hflip = no
# vflip = no
# shutter-speed = 0
```

Uncomment and set both `hflip` and `vflip` to `yes`:

```
hflip = yes
vflip = yes
```

To save and close the editor press: `Ctrl-X` to Exit, `Y` to save changes, and `Enter` to confirm.

After reloading the server with: `sudo systemctl restart uv4l-raspicam.service` you should see that stream now has a proper first-person view.

Step 8: Running the demo application

The demo application provides an interface to control the servos and lights on the Pan-Tilt HAT

Install the necessary dependencies:

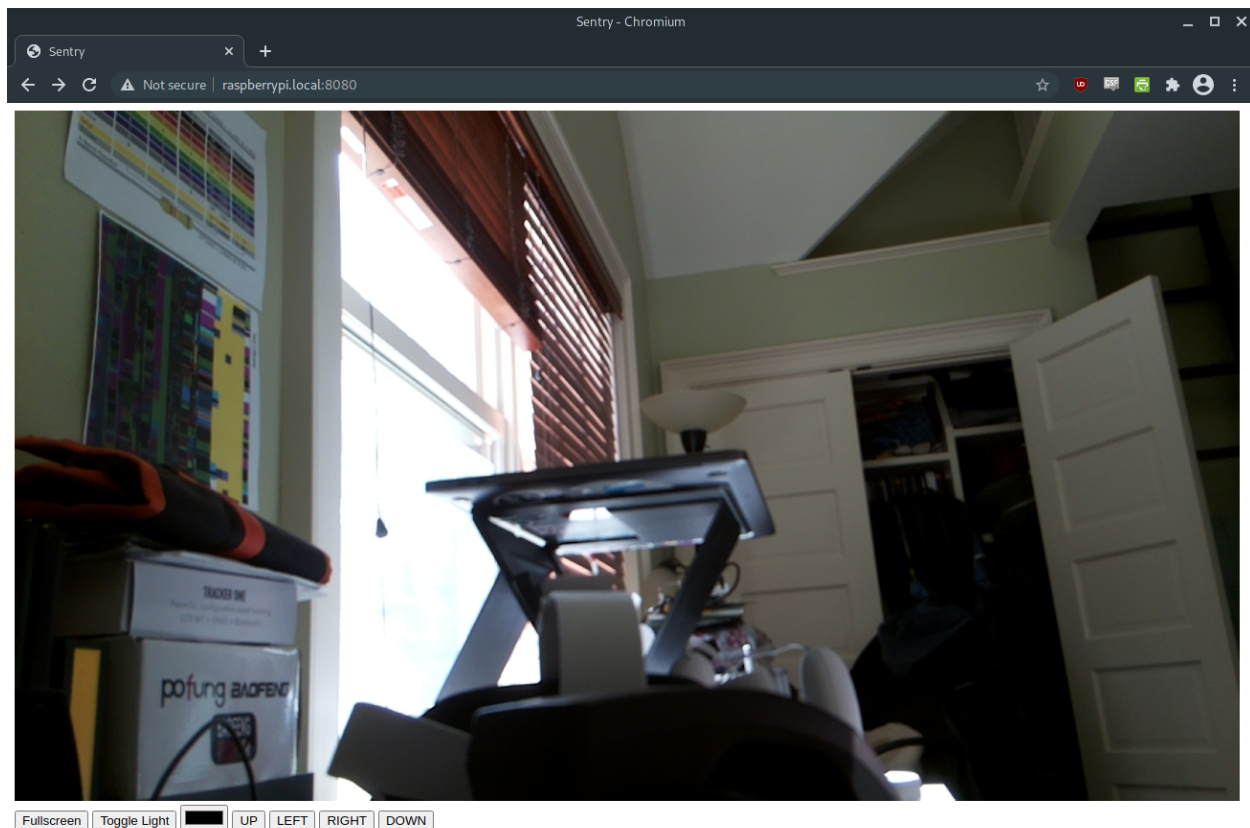
```
sudo apt install git python3-pantiltthat python3-smbus python3-flask
```

Download and run the Python application:

```
git clone https://github.com/nrobinson2000/vr-sentry
cd vr-sentry/app
python3 app.py
```

Now if you open the following URL in your browser you should be presented with the demo application:

```
http://raspberrypi.local:8080
```



Conclusion

That's it for this tutorial. In the next tutorial, we'll create a Unity application that will provide us with an interface to view and control the camera feed from within the Oculus Quest 2.

In the meantime, you should be able to use the demo application in the Oculus browser. If you click the **Fullscreen** button the video feed will expand to fill your perspective. You can click on the left and right sides of the feed to rotate the camera.

If the Quest cannot resolve `raspberrypi.local` try the IP address of the Pi.