LFS261:
DevOps and SRE Fundamentals - Implementing Continuous Delivery

- V7.11.2025 -

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Lab 1. Setting up the Learning Environment

By the end of this lab exercise, you should be able to:

- Create a Google Cloud Platform (GCP) account
- Configure a VM on GCP
- Connect to a VM on GCP
- Install Docker on Linux VM
- Verify that git is installed

First, sign up for Docker Hub at https://hub.docker.com/**.**

Create a Google Cloud Platform Account

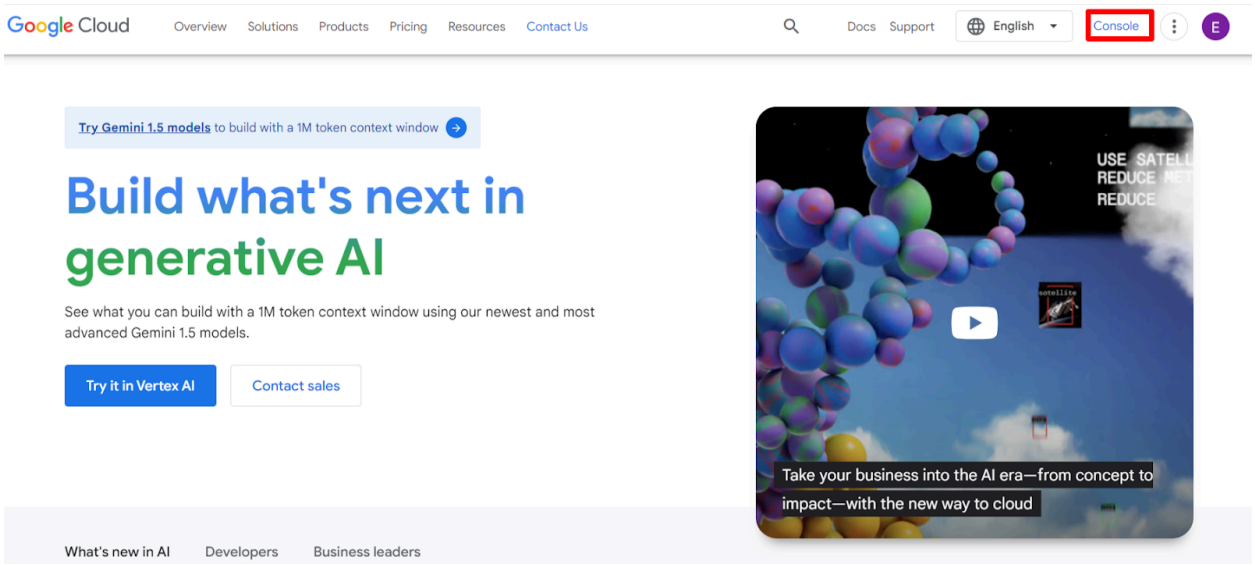
The only prerequisite for this task is a Google account. If you do not have one, go to google.com, select **Sign in** and follow the directions.

To get started, visit cloud.google.com and follow the simple steps to create a Google Cloud account. You can begin with a free account and sign up for free credits, which are valid for a limited time.

While creating an account, choose the account type **individual** and provide your address and payment details to complete the signup.

Once you create a Google Cloud Platform account, you will get Console access. You can revisit your account by going to cloud.google.com at any time.

Once logged in, you should see your Google Cloud Console, as pictured below:

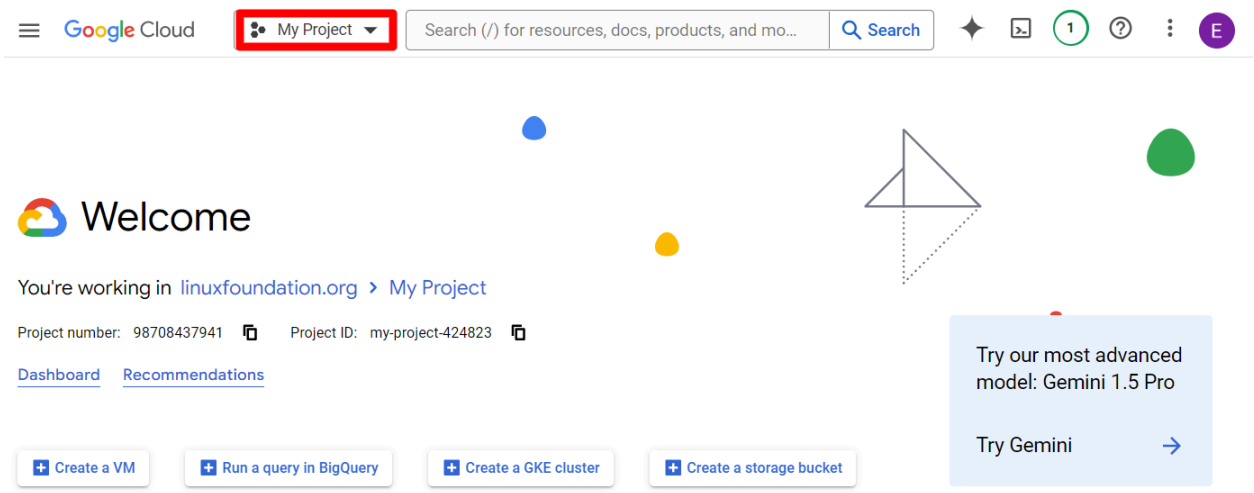


Alternatively, you can visit the console directly with this link: https://console.cloud.google.com.

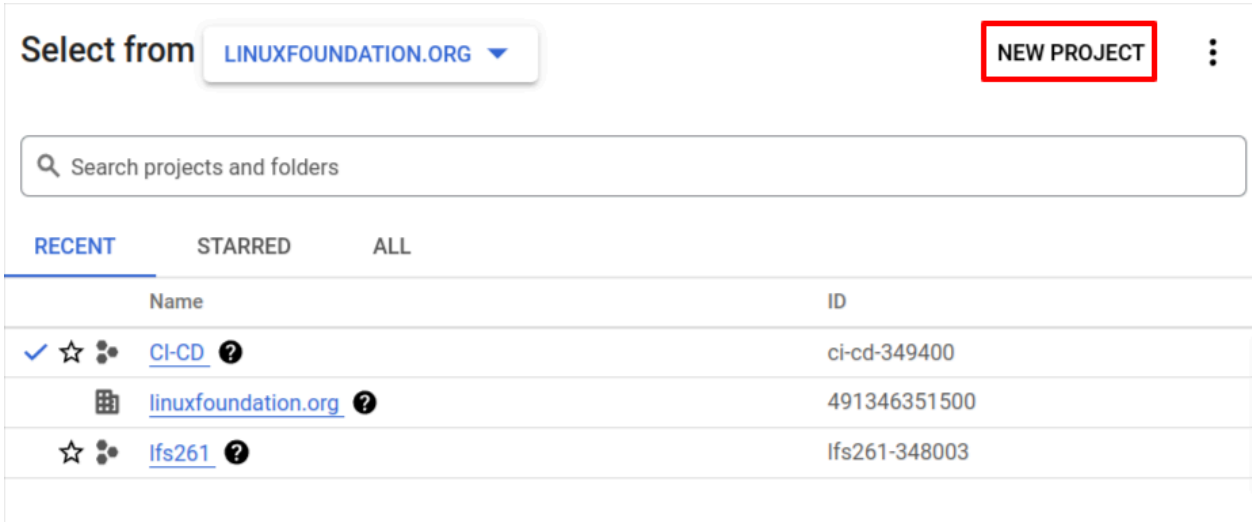
Creating a Project to Contain Your VM

According to Google Cloud documentation, a *"project in Google Cloud Platform (GCP) organizes all of your Google Cloud resources, including Cloud Storage data, Compute instances, monitoring and logging data, and App Engine instances. Projects also include associated permissions for these resources".*

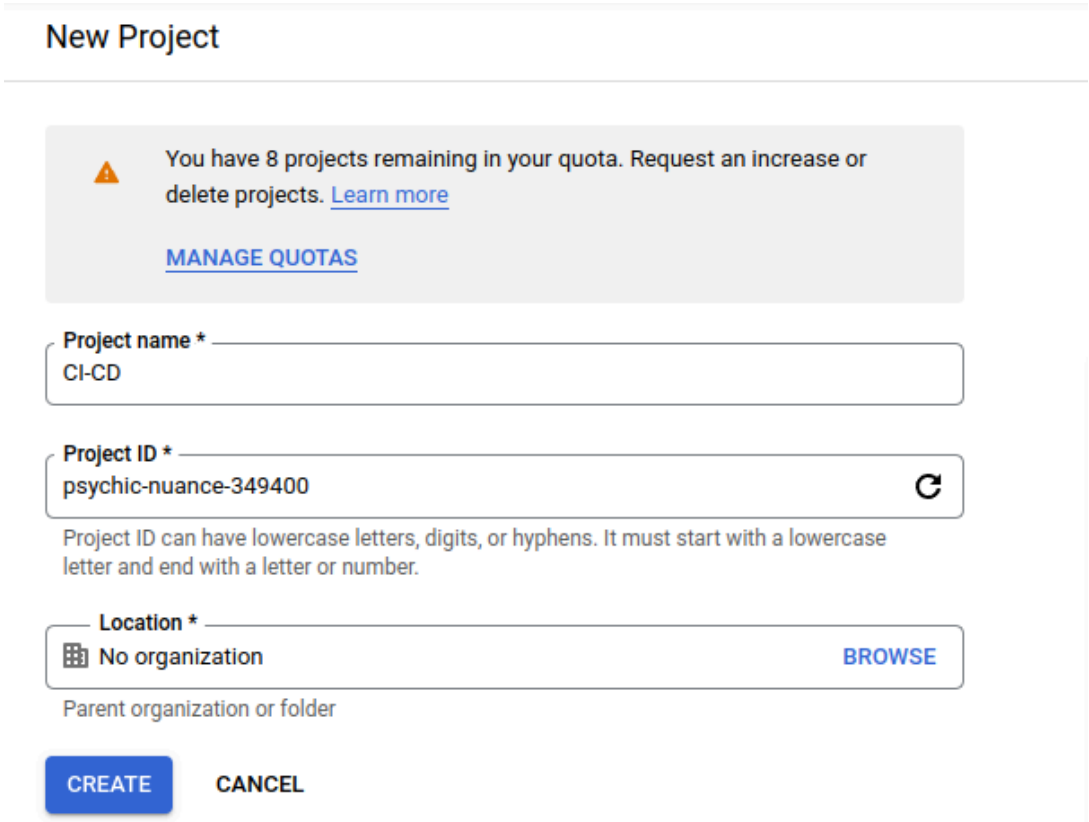
A project provides a namespace to isolate resources for that project. To set up a new project, select the project dropdown menu. If it is your first time, you will see **My First Project** in the box. Otherwise, you will see the last project that you were in. To create a new project, click inside the box as illustrated below.



Select **NEW PROJECT**.

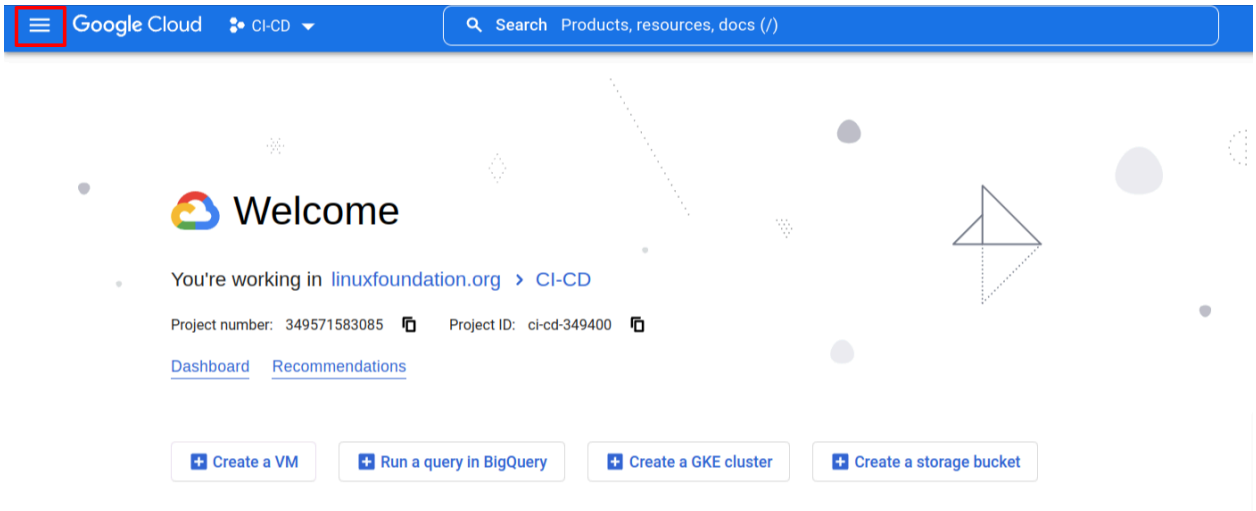


Name the project **CI-CD** and click **CREATE**.

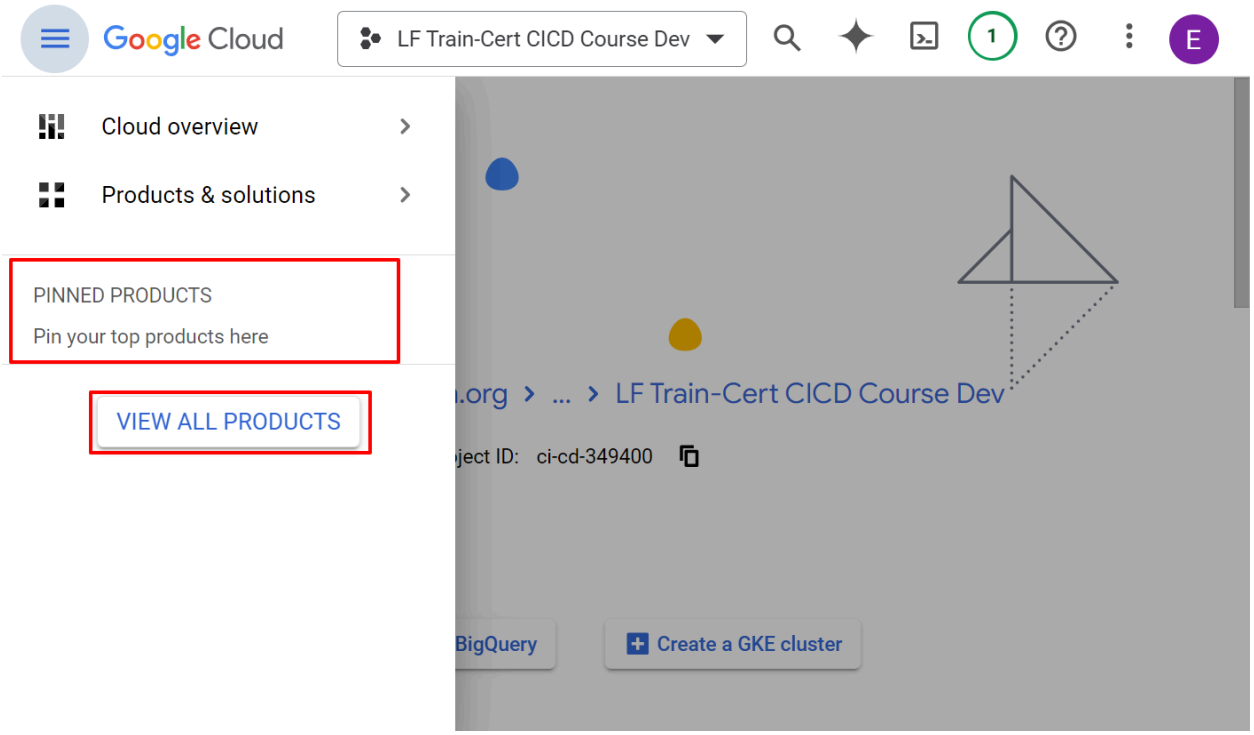


Navigating to VM Instances on Google Cloud

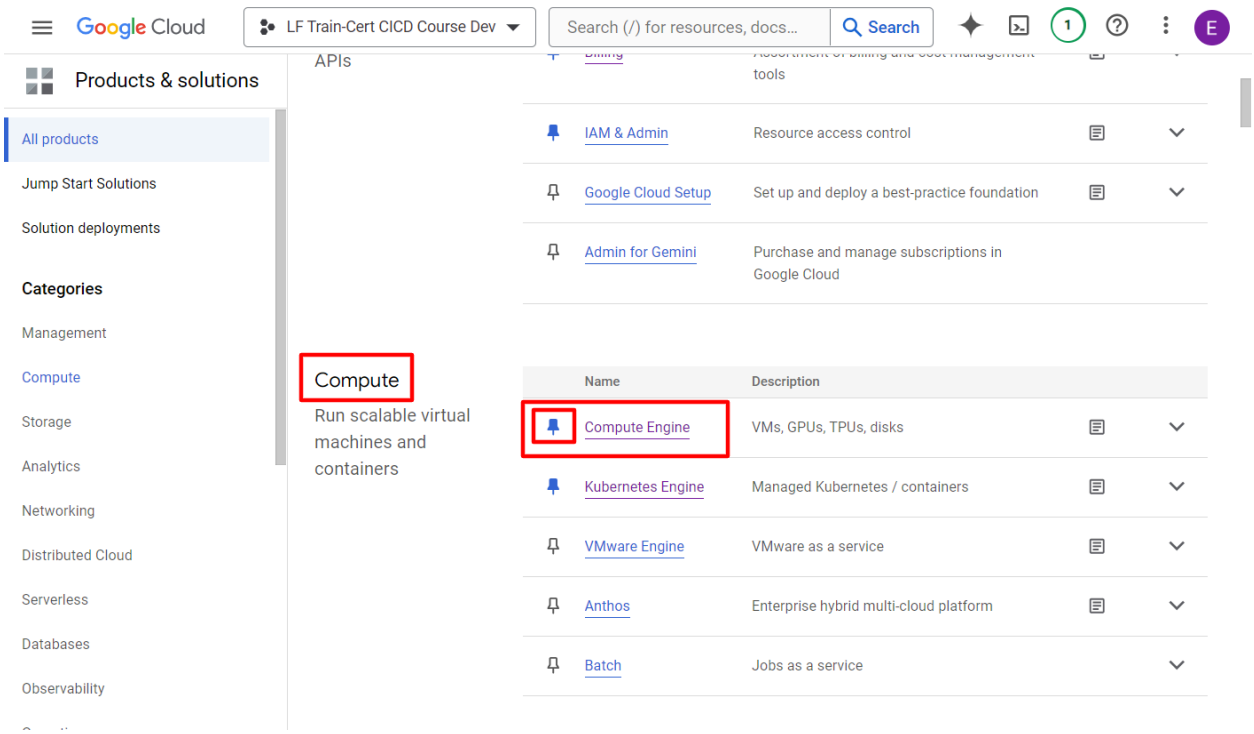
Open the menu in your Google Cloud account by clicking the menu in the top left:



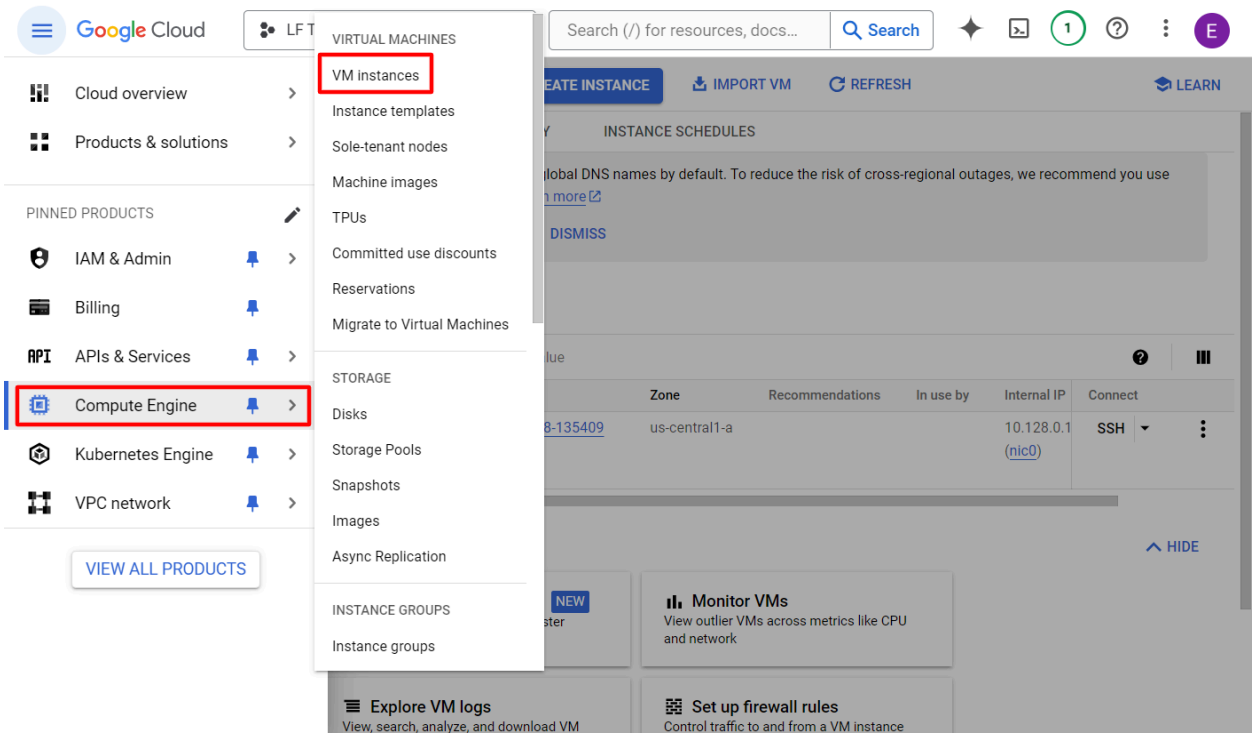
The flyout menu has two sections. Look for **Compute Engine** in the **PINNED** or **VIEW ALL PRODUCTS** sections. If **Compute Engine** is not in the **PINNED** section, click **VIEW ALL PRODUCTS**:



Find **Compute Engine** and then click the **pin icon**.



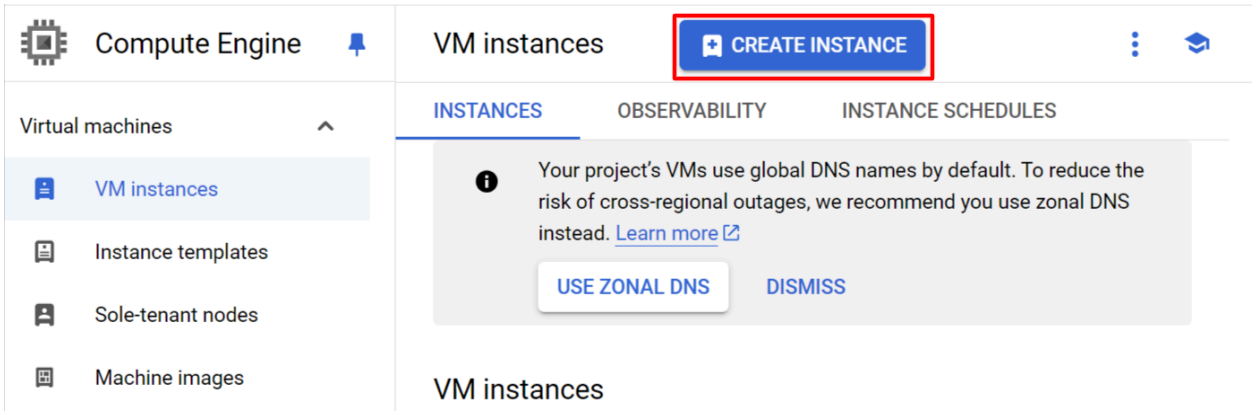
Navigate to **Menu > Compute Engine > VM instances:**



This will bring you to the VM instances page where you can create your VMs and see any VMs that have already been created.

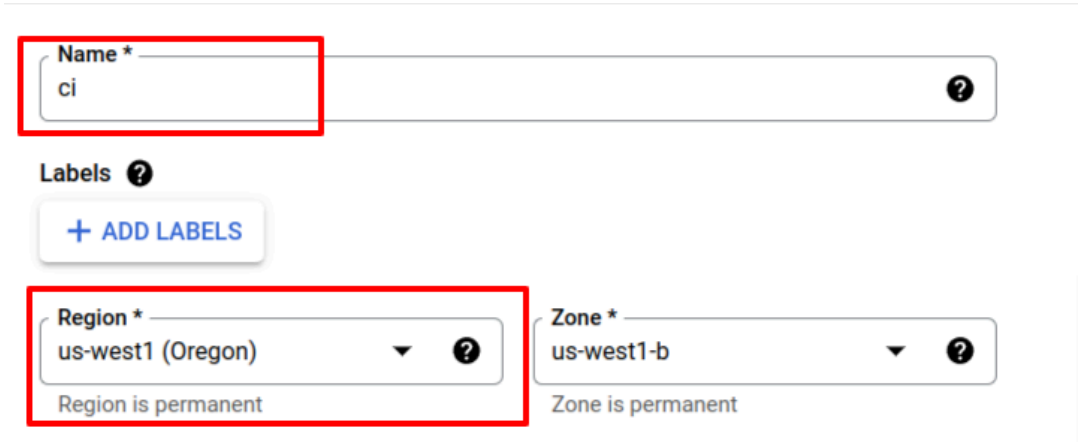
Creating a VM Instance

To bring up the UI for creating a new VM instance, select **CREATE INSTANCE** at the top of the page:

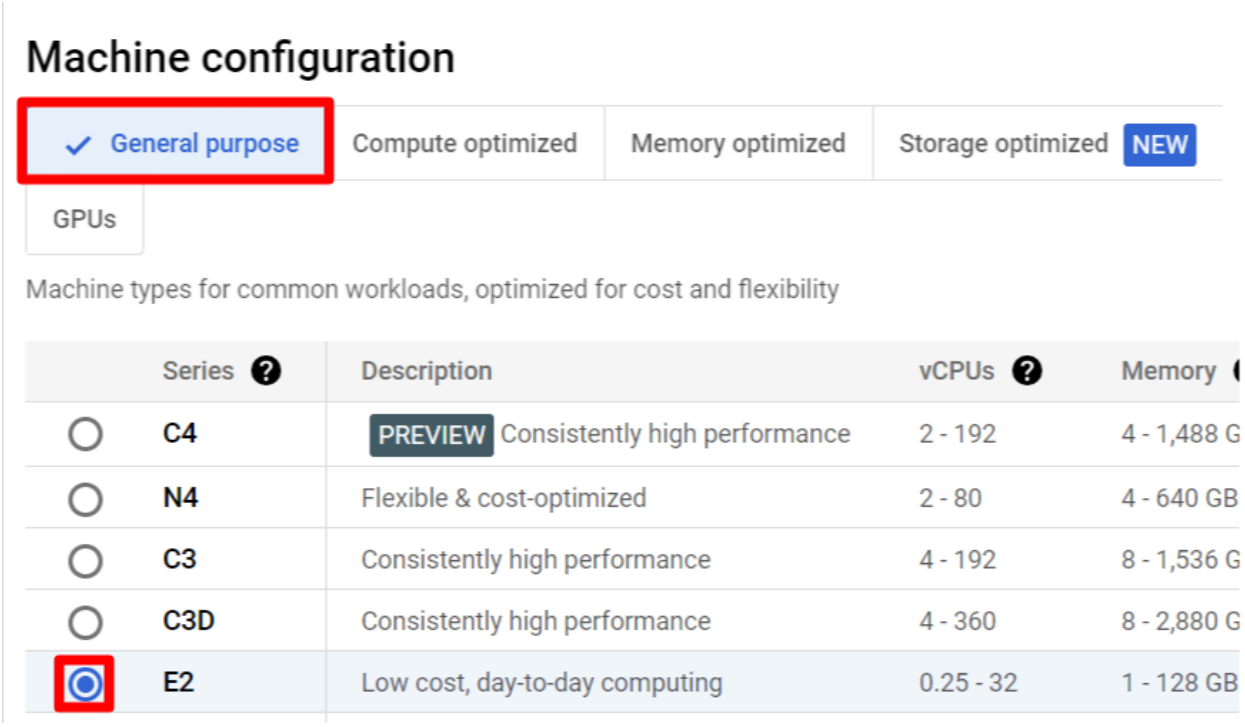


You can give the instance a name that is meaningful to you. In this example, the VM instance is named **ci.**

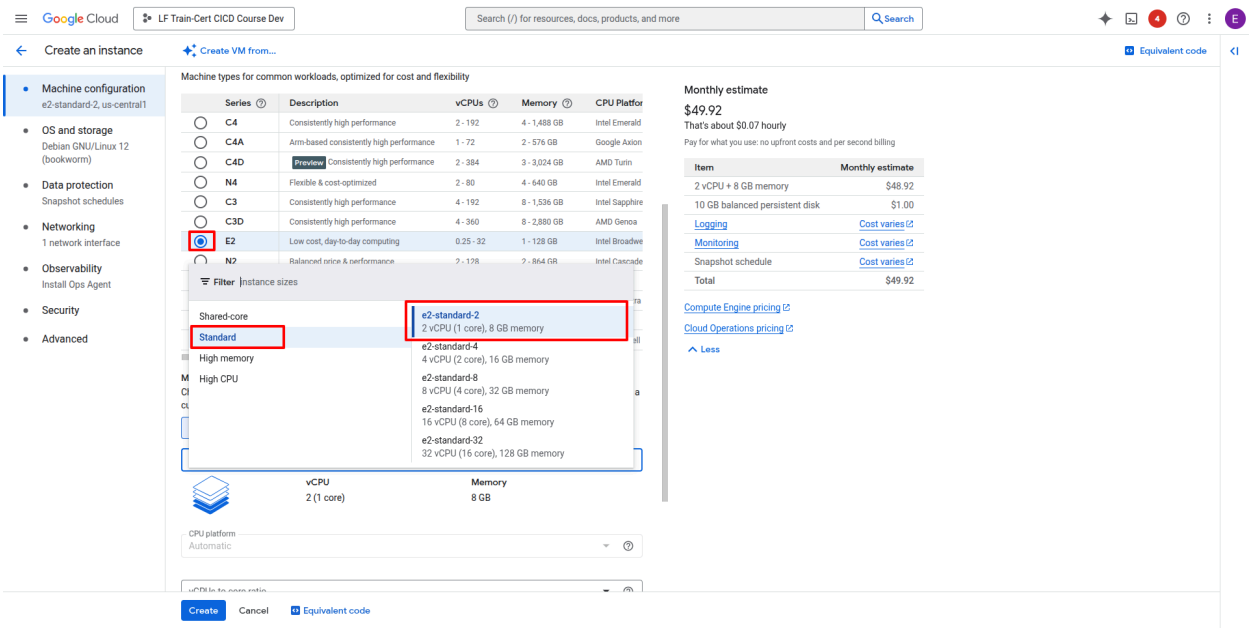
Choose the **Region** that is closest to you. In this example, we have chosen **us-west1 (Oregon)**.



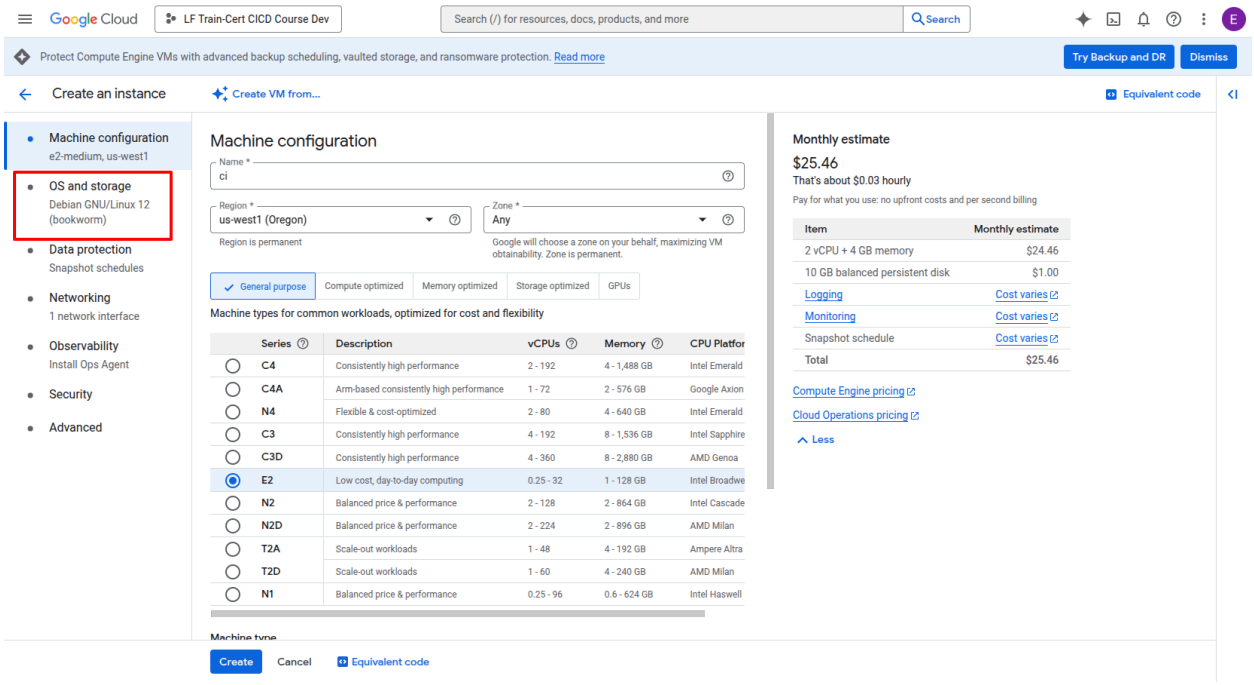
Scroll to **Machine Configuration**. Select **E2** under the **General purpose** tab.



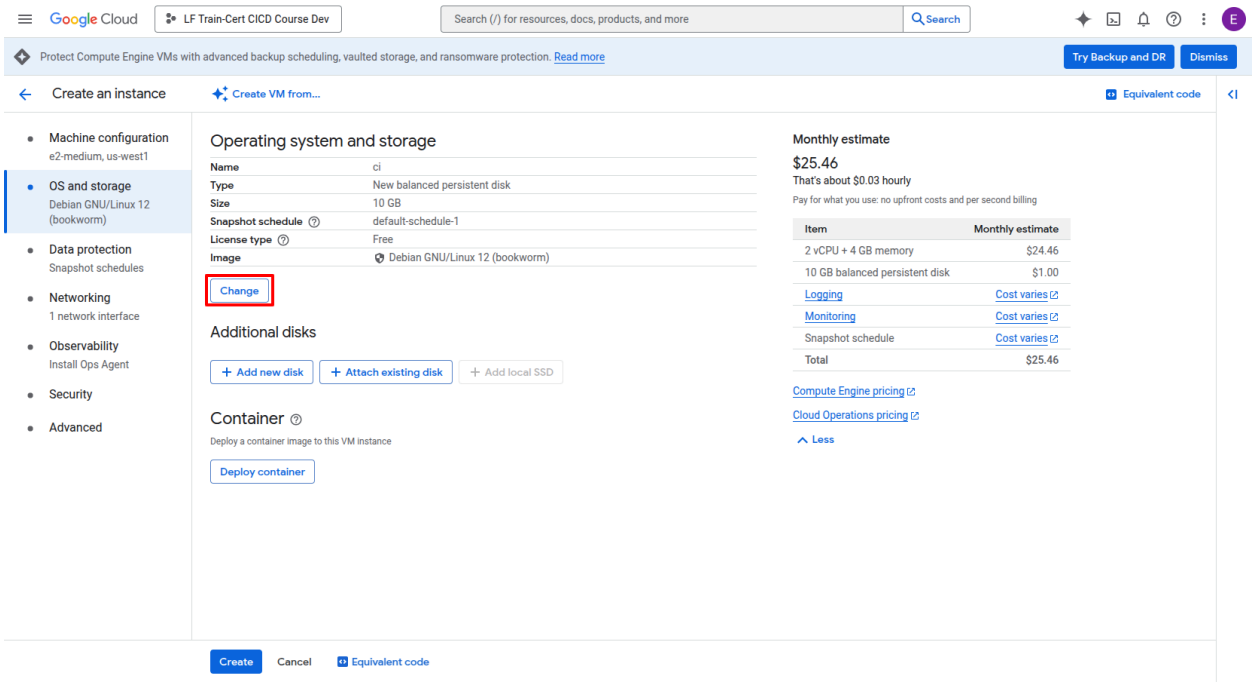
Scroll to **Machine type**. For machine type, choose **e2-standard-2 (2 vCPU, 8 GB memory)**.



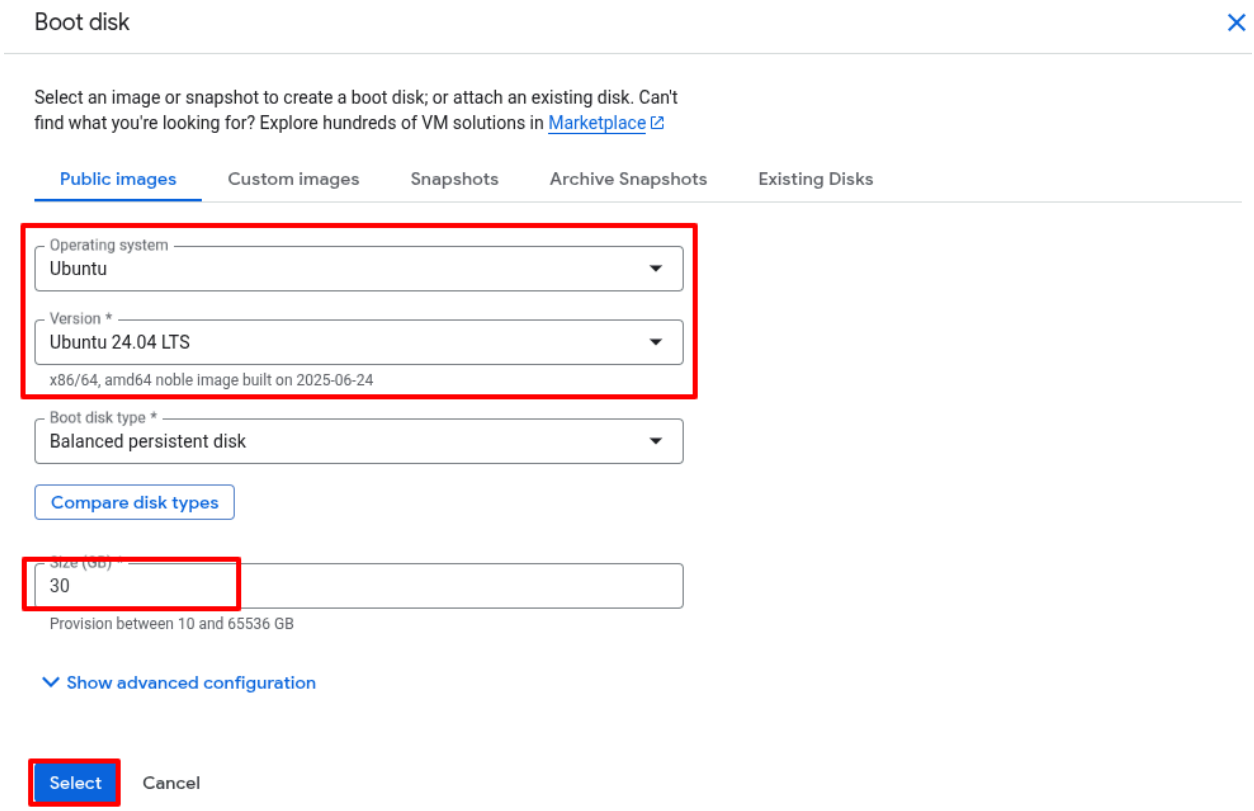
Click **OS and storage** on the right.



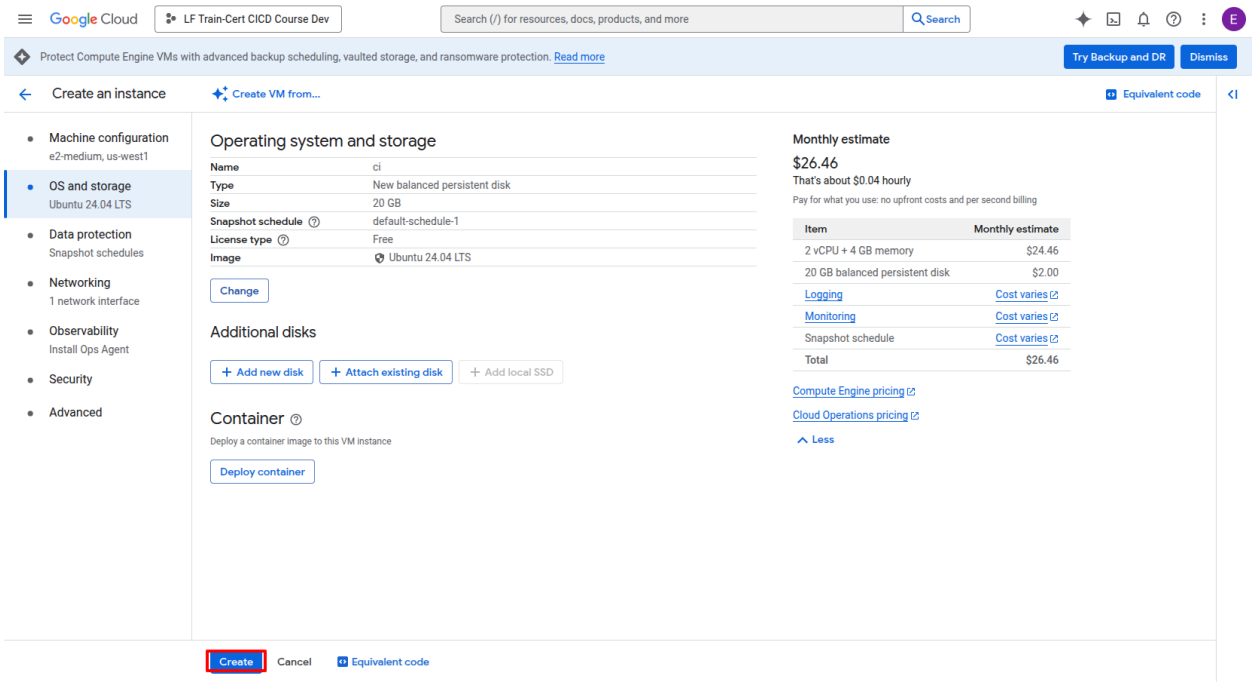
Scroll to **Boot disk** and select **CHANGE**:



This will bring up a form that allows you to choose the operating system you want to run. As we decided to use Ubuntu 24.04 for lab exercises, choose **Operating system > Ubuntu.** Choose the **x86** version of **Ubuntu 24.04**. Enter **30** for the **Size**. Then, click **Select**.

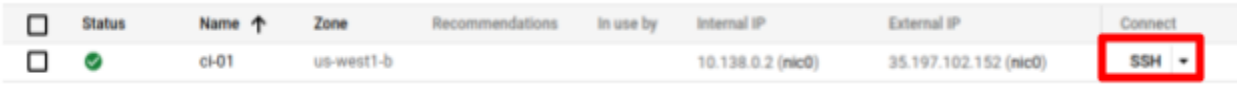


Scroll to the bottom of the VM creation form and click **CREATE**.

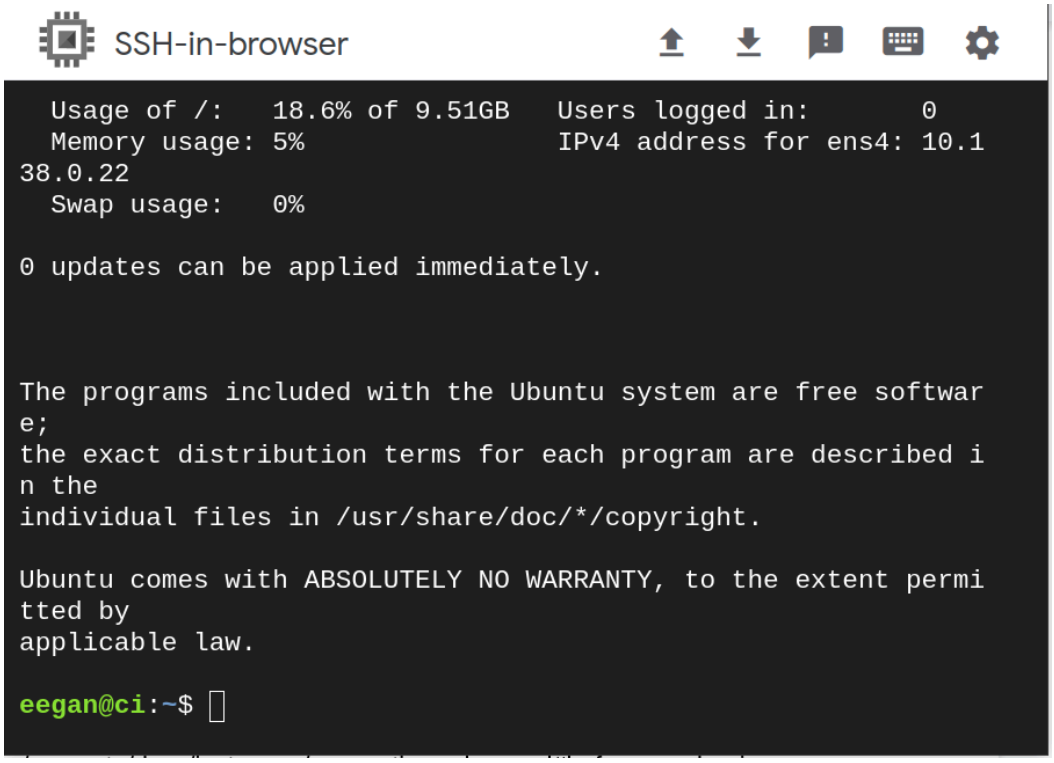


Connecting to Your VM Instance

You will be taken back to the **VM instances** page where you will see your newly created VM. To connect to your VM, click **SSH**.



A terminal window will pop up.



You are inside a Linux Ubuntu machine. This is a terminal that you can use to interact with your VM on GCP.

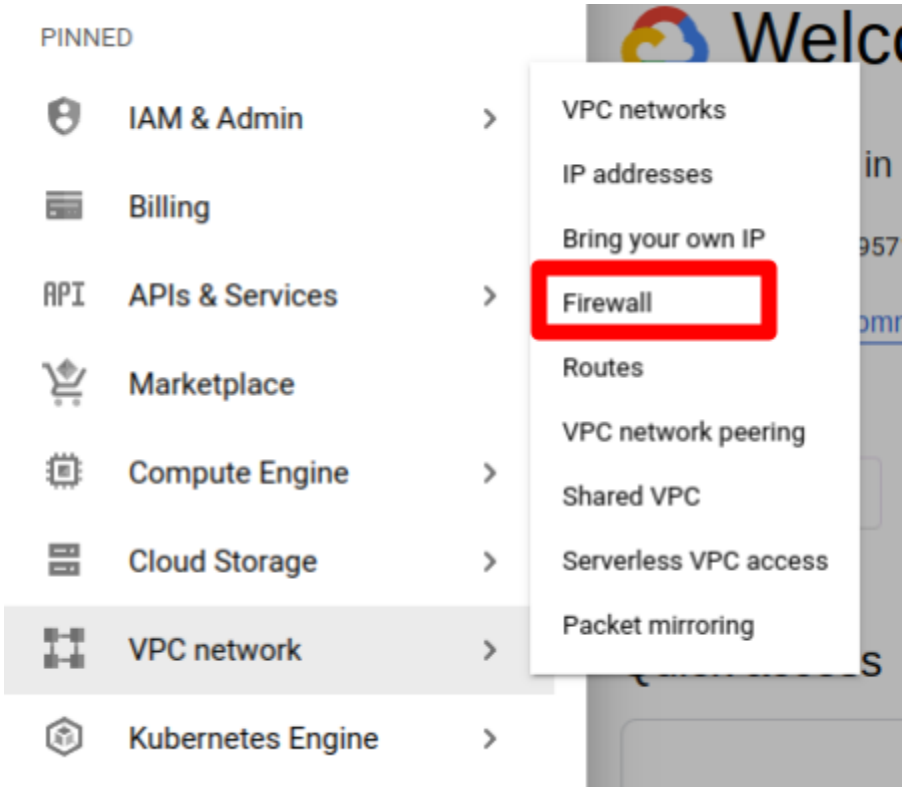
If you would like to connect to a Google Cloud VM instance from a terminal on your own computer, you will need to follow the directions here: https://cloud.google.com/compute/docs/instances/connecting-advanced#before-you-begin

Opening the Firewall for Our Google Cloud VM

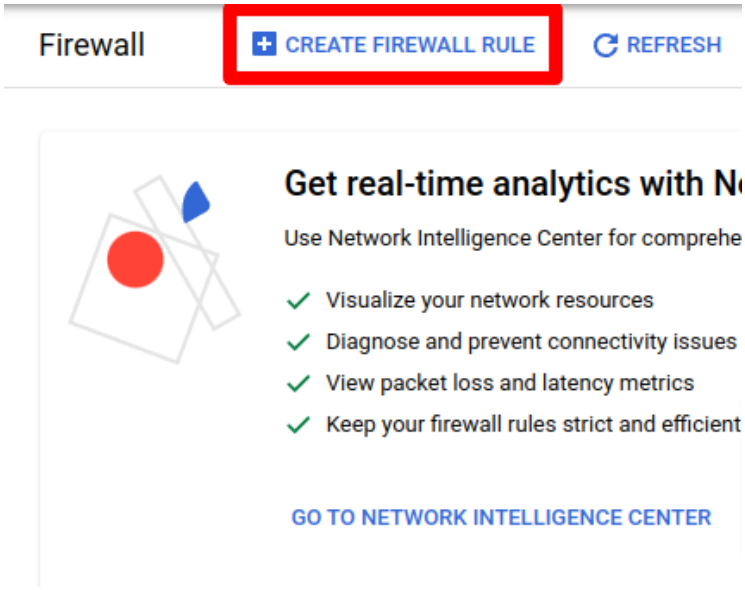
When learning new concepts, it is helpful to configure our learning environments in a way that allows us to focus on the topic at hand. In our case, we don't want to worry about whether the issues we are running into are network-related or due to the tools we are learning. This is not a networking course. As such, we will open our firewall completely to rule out any firewall issues. This is only for learning purposes. **This is *NOT* something you would do in production, as it is *NOT* secure.** However, it will help you troubleshoot a CI/CD pipeline.

Creating a Firewall Rule

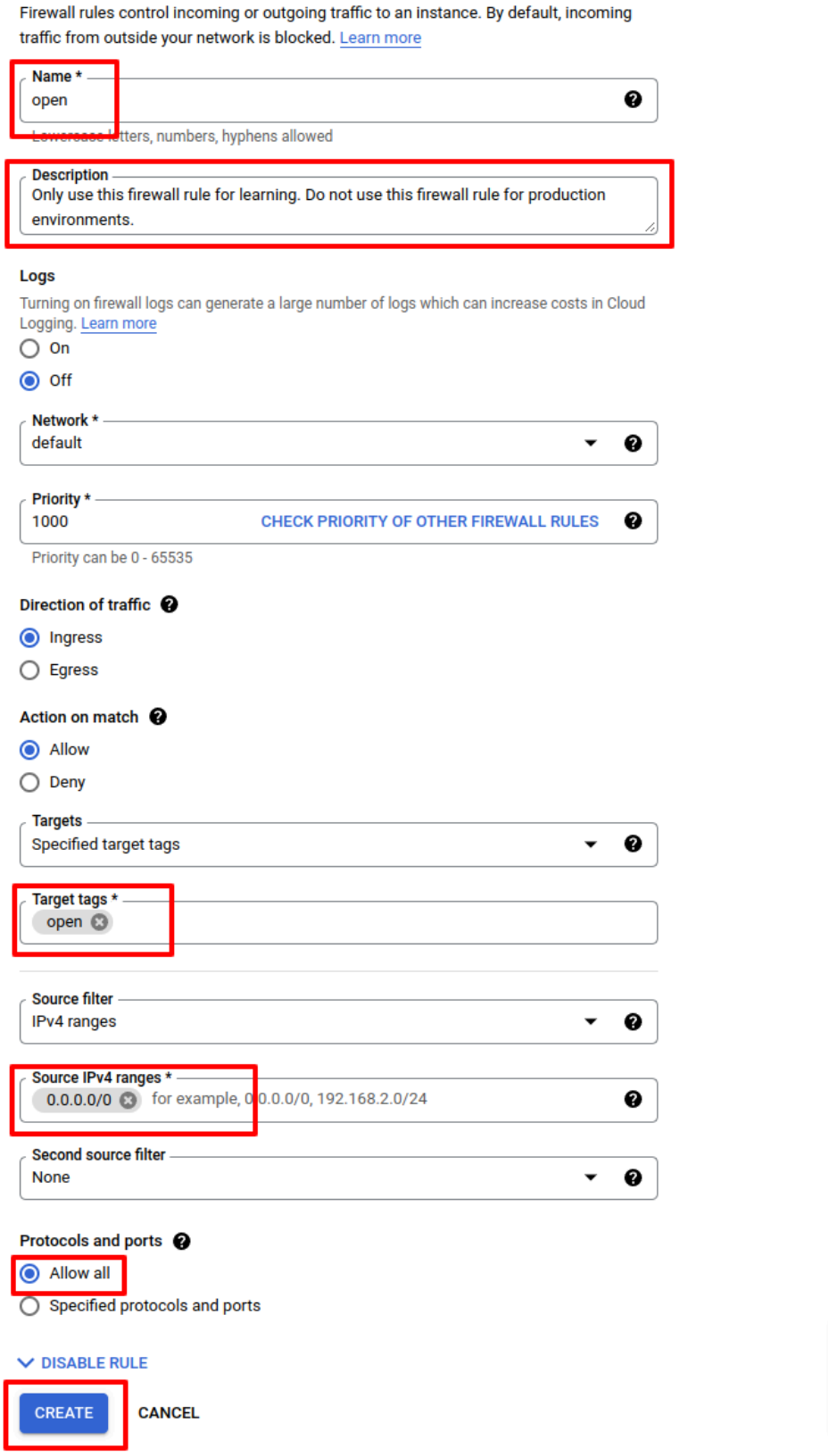
Under the **VPC network** go to **Firewall**.



In networking, it is common to create **rules** that are then **applied** to specific computers or VMs. We will create a **Firewall rule** and then apply it to our VM instance.



Refer to the following screenshot:



Name the firewall rule **open** and give it a description. In our case, we have reminded ourselves NOT to use this rule in production.

Then, under **Target tag,** enter **open**. This is how you will add this rule to your VM instance. You need to remember this or look it up to add it to your VM. To make it easy, give this firewall rule the same tag as the name of the firewall rule.

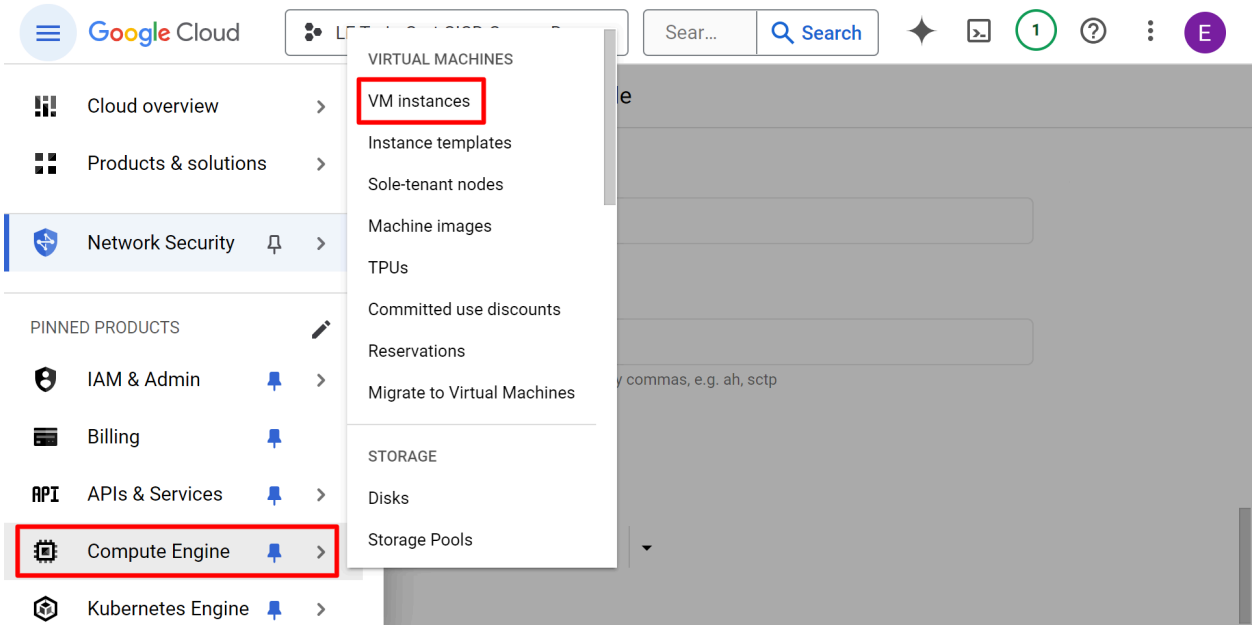
Under **Source IPv4 Ranges** we will enter `0.0.0.0/0`. `0.0.0.0/0` is networking for *all IP addresses*. This means that your VM can be connected to from *any computer.* As noted, this is highly insecure, but it is good for learning.

Under **Protocols and ports** select **Allow all** and then click **CREATE**.

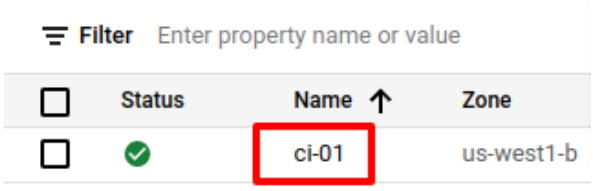
Adding the Firewall Rule to Our VM

Now we have a firewall rule that will allow *all* traffic through. A rule is of no use unless it is applied to something. In this case, we want to apply it to our VM.

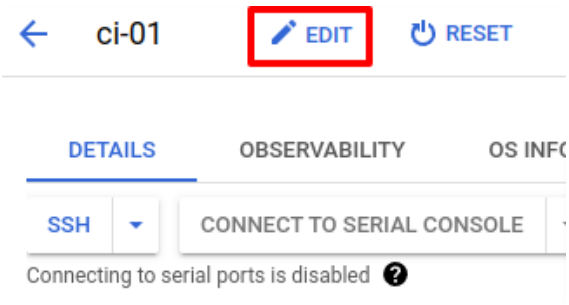
First go to **Compute Engine > VM instances**.



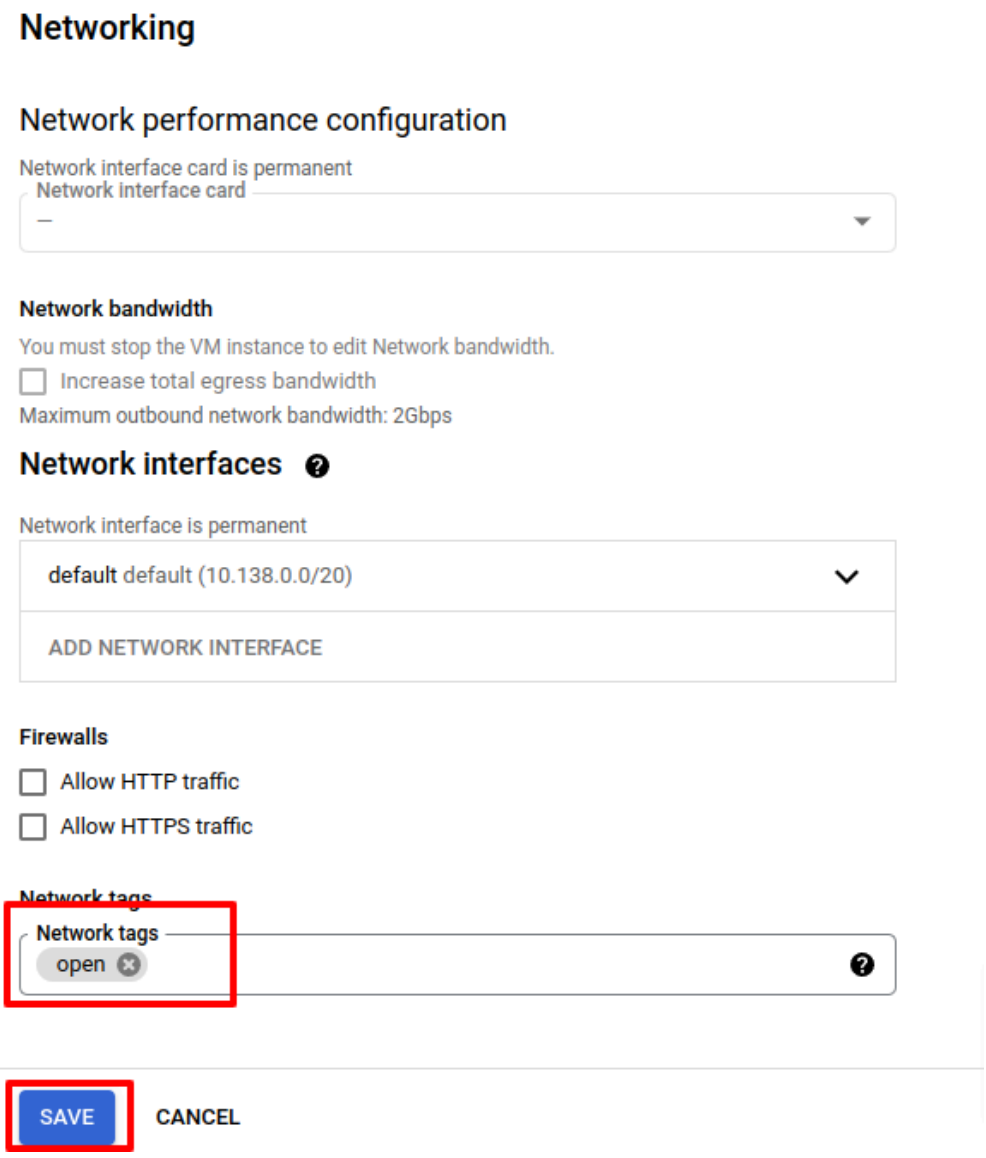
Click on your VM's name.



Click **EDIT** at the top of the screen.



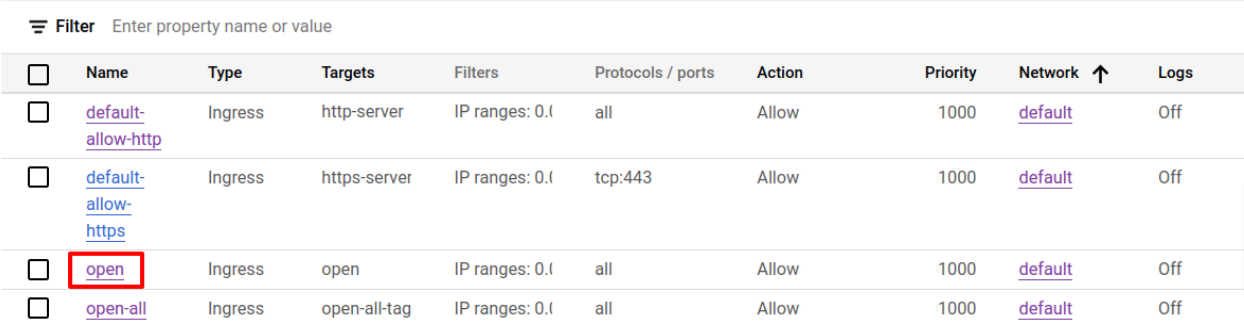
Scroll down to **Networking** if it isn't visible.



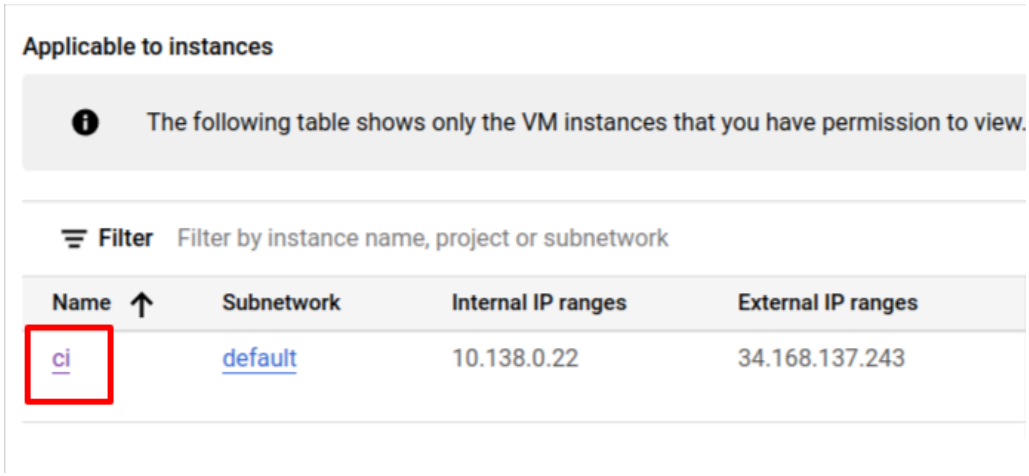
Enter **open** in the **Network tags** box. Remember, this is what we tagged our firewall rule earlier.

Verify the Rule Was Applied

To verify that the instance is associated with the **open** firewall rule, return to **Google Cloud > VPC Network > Firewall**. Click on the **open** firewall rule.



Then scroll down to **Applicable to Instances**.



You should see your VM listed.

Installing and Verifying Docker on Your Linux VM

The following directions have been pulled directly from Docker's documentation. Run each command in the order in which they appear. The first command ensures that any existing Docker versions are removed, preventing conflicts with the new version we will install. If Docker is not installed, the output will inform you that Docker was not found. Either outcome is fine.

```
$ sudo apt-get remove docker docker-engine docker.io containerd runc
```

Now that you have removed or ensured that no Docker is present on the machine, we can proceed with the install.

```
$ sudo apt-get update
```

```
$ sudo apt-get install \
    ca-certificates \
    curl \
    gnupg \
    lsb-release
```

```
$ curl -fsSL https://download.docker.com/linux/ubuntu/gpg | sudo gpg --dearmor
-o /etc/apt/keyrings/docker.gpg
```

```
$ echo \
```

```
  "deb [arch=$(dpkg --print-architecture)
signed-by=/etc/apt/keyrings/docker.gpg]
https://download.docker.com/linux/ubuntu \
```

```
  $(lsb_release -cs) stable" | sudo tee /etc/apt/sources.list.d/docker.list \
> /dev/null
```

```
$ sudo apt-get update
```

```
$ sudo apt-get install docker-ce docker-ce-cli containerd.io
docker-buildx-plugin docker-compose-plugin
```

Type **Y** when prompted.

The directions are found here: https://docs.docker.com/engine/install/ubuntu/.

After installation, validate Docker by running the following commands:

```
$ sudo docker version
```

```
Client:            Docker Engine - Community
Version:           28.0.4
……..
Server: Docker Engine - Community
Engine:
Version:          28.0.4
……….
```

Do a smoke test with:

```
$ sudo docker run hello-world
```

```
……
```

```
Hello from Docker!
```

```
This message shows that your installation appears to be working
correctly.

…..
```

This validates that Docker has successfully been installed.

Add your user to the **docker** group. This will make it more convenient to run commands, as you won't need to type **sudo** every time you run Docker.

WARNING: In a production environment, this has significant security implications that must be carefully weighed.

There is no one-size-fits-all answer as to whether you should add users to the **docker** group.

```
$ sudo usermod -aG docker $USER
```

```
$ newgrp docker
```

You should now be able to run **docker** commands without typing **sudo** first.

Verifying and Installing Git

Git comes pre-installed on most Linux distributions. To verify, run:

```
$ git version
```

If it is not installed, reference the official download and installation guides below to set up Git:

- Git - Downloads
- Installing Git

Summary

You are now set up to get started with the hands-on lab exercises in the rest of the course.

Lab 2. Getting Started with Docker

By the end of this lab exercise, you should be able to:

- Launch containers with Docker
- List common options used with the **`docker container run`** command
- Run web applications and access them with port mapping
- Manage container lifecycle and learn how to debug them
- Clean up

Validate the Setup

Begin by checking the Docker version you have installed using the following command:

```
docker version
```

Validate further by running a smoke test:

```
docker run hello-world
```

This should launch a container successfully and show you a **`hello world`** message.
This smoke test validates the following:

- You have Docker client installed
- Docker daemon is up and running
- Docker client is correctly configured and authorized to talk to Docker daemon
- You have non-blocking internet connectivity
- You are able to pull an image from Docker registry and run a container with it

Launching Your First Container

Before launching your first container, open a new terminal and run the following command to

analyze the events of the Docker daemon:

```
docker system events
```

When you run the above command, you may not see any output. Keep this window open, and it will start streaming events as you proceed to use the Docker CLI in another window.

Now, launch your first container with the following command:

```
docker container run alpine ps
```

where,

- **`docker`** is the command line client
- The **`container run`** command is used to launch a container. You can alternatively just use the **`run`** command here
- **`alpine`** is the image
- **`ps`** is the actual command which is run inside this container

Create a few more containers with the same image but with different commands as follows:

```
docker container run alpine uptime
```

```
docker container run alpine uname -a
```

```
docker container run alpine free
```

You can check the events in the window where you started running the **`docker system events`** command earlier. It shows what is happening on the Docker daemon side.

Listing Containers

Check your last run container using the following commands:

```
docker ps -l
```

```
docker ps -n 2
```

```
docker ps -a
```

where,

- **`-l`**: last run container
- **`-n xx`**: last xx number of containers
- **`-a`**: all containers (even if they are in a ‘stopped’ state)

Learning About Images

Containers are launched using images which are pulled from the registry. Observe the following command:

```
docker container run alpine ps
```

Here, the image name is **alpine** , which can actually be expanded to:

```
registry.docker.io/docker/alpine:latest
```

where the following are the fields:

- registry: **registry.docker.io**
- namespace: **docker**
- repo: **alpine**
- tag: **latest**

Use the following commands to list your images from your local machine and pull the **nginx** image from DockerHub. Examine the layers of an image with the **history** command:

```
docker image ls
```

```
docker image pull nginx
```

```
docker image history nginx
```

Default Run Options

You have learned how to launch a container. However, this container is ephemeral and exits immediately after the command is run. To make the container persistent and to be able to interact with it, let's try adding a couple of new options:

```
docker run -it alpine bash
```

where,

- **-i**: (interactive) provides standard in to the process running inside the container
- **-t**: provides a pseudo-terminal in order to interact

You could further add the **--rm** options to ensure the container is deleted when stopped:

```
docker run --rm -it alpine sh
```

Note: Use ^d to come out of the shell opened within the container.

Another useful option is **-d**, which will launch the process in a contained environment and

detach from it. This allows the container to keep running in the background:

```
docker container run -idt --name redis redis:alpine
```

Launching and Connecting to Web Applications

So far, you have launched a few simple containers with one-off commands. It's time to learn how to launch a web application and connect to it.

You could launch a container with the **`nginx`** web server as follows. Observe the new **`-p`** option:

```
docker container run -idt -p 8080:80 nginx
```

where,

- **`-p`** allows you to define a port mapping
- **`8080`** is the host-side port
- **`80`** is the container-side port, the one on which the application is listening

Once you configure the port mapping, access that application on your browser by visiting **`http://IPADDRESS:8080`**.

***NOTE**: Replace **`IPADDRESS`** with the *actual IP* in case your Docker host is remote, or with *localhost* if using Docker Desktop.*

With the command above, using the **`-p`** option, you explicitly define the host-side port. You can also have Docker pick the port automatically with the **`-P`** option:

```
docker container run -idt -P nginx
```

where,

- The host port is automatically chosen and incremented starting with 32768.
- The container port is automatically read from the image.

As usual, use **`docker ps`** commands to observe the port mapping.

Troubleshooting Containers

To debug issues with the containers, which are nothing but processes running in an isolated environment, the following could be two important tasks:

- Checking process logs
- Being able to establish a connection inside the container (similar to ssh)

You will learn about both in this subsection.

To start examining logs, find your container ID or container name using the following command:

```
docker ps
```

You can use the command below to find logs for a container named **redis**:

```
docker logs redis
```

You have an option of replacing the **redis** name with the actual container ID (the first column in the output of the **docker ps** command).

You can follow the logs using the **-f** option. **docker exec** allows you to run a command inside a container:

```
docker logs -f redis
```

Note: Use ^c to exit

The **exec** command allows you to connect to the container and launch a shell inside it, similar to an ssh connection. It also allows running one-off commands:

```
docker exec redis ps
```

```
docker exec -it redis sh
```

With the **logs** and **exec** commands, you should be able to get started with essential debugging.

Exercise: Stop, Remove and Clean Up

With the knowledge gained thus far, set up the following two apps with Docker:

- Nextcloud
- Portainer

Try launching it on your own before proceeding with the solutions below.

Here, you will learn how to stop, remove, and clean up the containers that you have created.

Find your container ID and stop the container before removing it. You can stop containers using the name or the ID of the container. You can also stop multiple containers at once, as follows:

```
docker stop redis
```

```
docker stop b584 84e6 e4da
```

where,

- **ac69 b584 84e6 e4da** are container IDs (as per the above example)

These could vary on your system. Use the ones you see when you run the **docker ps** command. You can start a container that is in a stopped state with:

```
docker start redis
```

To remove a container (destructive process) that is stopped, use:

```
docker stop redis
```

```
docker rm redis
```

If the container is in a running state, it cannot be stopped unless a **force** option is used:

```
docker container run -idtP --name web nginx
```

```
docker rm web
```

```
docker rm -f web
```

Images are independent of containers. You can remove images using the following commands:

```
docker image rm 4206
```

```
docker image rm 4f1 4d9 4c1 9f3
```

```
docker image prune
```

where **4206** and **4f1 4d9 4c1 9f3** are the beginning characters of the image IDs on our host. You can get all your Docker system information by using **docker system info**.

Setting Up Nextcloud

You should now have some insight into running applications using containers. Next, you will set up the Nextcloud application using the official image, creating a volume and mounting it inside the container. Because of the documentation, we know the container directory we must mount our volume to is **/var/www/html**. You may look at it for your information, but it is not necessary.

Follow these steps to set up Nextcloud:

```
docker container run -idt -P -v nextcloud:/var/www/html nextcloud
```

You will see Docker download the image and finally print the container ID.

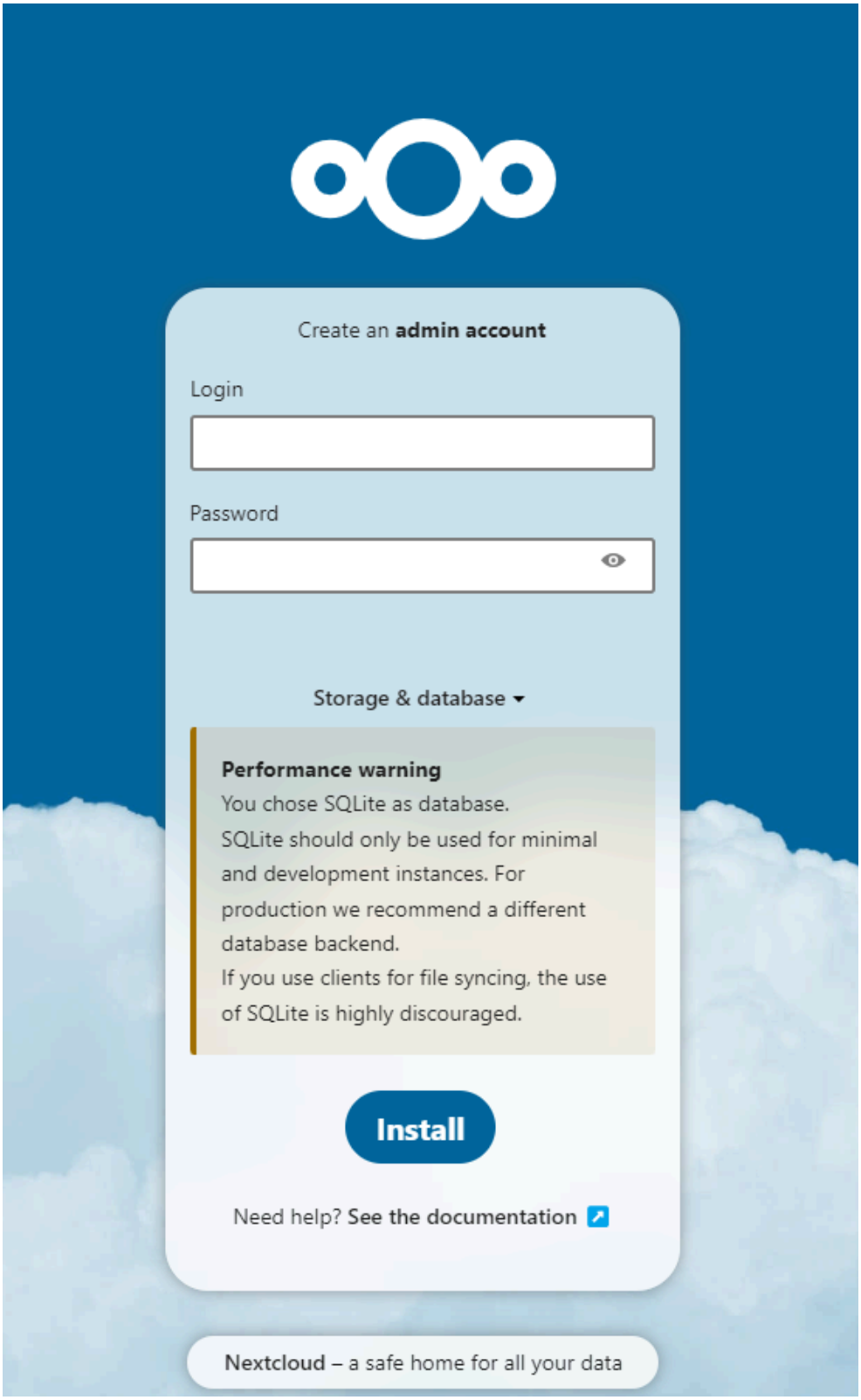
Use the following commands to get the running container port and logs:

```
docker ps
```

```
docker logs ac69
```

```
docker logs -f ac69
```

Example: You can visit the application by using `localhost:32770` on your browser.



Setting up Portainer with Advanced `run` Options

Here, you will launch and practice more advanced **`run`** options using the Portainer application.

In this case, you need to create a volume before running the container and validate the volume by using the following commands:

```
docker volume create portainer_data
```

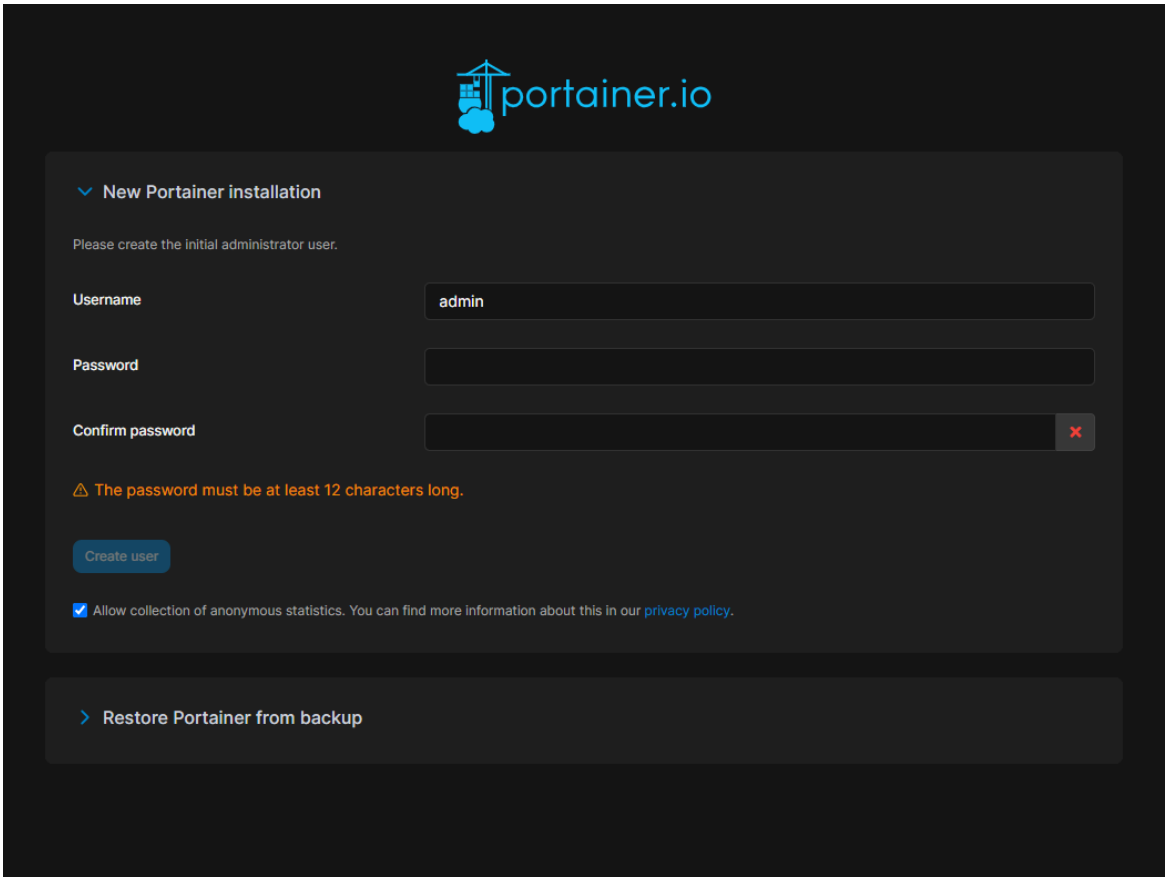
```
docker volume ls
```

```
docker volume inspect portainer_data
```

After creating the volume, run the **`docker container run`** command along with the volume which we have created:

```
docker run -d -p 9000:9000 -v
/var/run/docker.sock:/var/run/docker.sock -v
portainer_data:/data portainer/portainer
```

Access the Portainer application using port 9000 in your browser. To do this, enter **`localhost:9000`** or **`IPADDRESS:9000`** in your browser's address bar.



Cleanup

First, we need to stop any running containers. To get all running containers and their IDs, run:

```
docker ps
```

Keep the first set of unique characters of each container ID handy. These are all you need to enter after the command. Run:

```
docker stop containerID1 containerID2 containerID3…
```

Don't type the '...'. That is simply to indicate that you may have more containers.

Now that all the containers have been stopped, we can run:

```
docker container prune
```

Type 'y' to continue.

Finally, run:

```
docker system prune
```

Type 'y' to continue.

Get your images with:

```
docker image ls
```

Take note of the image IDs. Then run:

```
docker image rm imageID1 imageID2 imageID3…
```

Run:

```
docker system info
```

This should verify that you have 0 containers running, paused, and stopped.

Summary

In this lab, we spun up multiple Docker containers with different options. These options allowed us to interact with these containers through their shells and via networking. Finally, we cleaned up our Docker environment so that we could move on to other concepts with a clean slate.

Lab 3. Revision Control with Git

By the end of this lab exercise, you should be able to:

- Configure a Git client
- Create and work with repositories
- Understand the basics of revision control operations
- Understand basic branching and merging
- Work with remotes
- Resolve conflicts
- Leverage Docker for local development

Configuring Git Client

Before you start revision control, you need to configure Git. There are three different places you can configure Git, as explained here.

Git configs:

Type	Scope	Config Path
LOCAL	Repo	.git/config
GLOBAL	User	/home/user/.gitconfig
SYSTEM	System	/etc/gitconfig

You will create configurations with user scope, valid for all repositories created by the current user:

```
git config --global user.name "username"

git config --global user.email "user@gmail.com"

git config -l
```

```
cat ~/.gitconfig
```

You can also create additional configurations, e.g. to switch the default editor to a terminal text editor called *Vim*:

```
git config --global core.editor vim
```

To see the change, run the following command:

```
git config -l
```

To edit the configuration file, use the `-e` flag as follows:

```
git config -e --global
```

This will open the file in Vim. To exit Vim, type the following:

```
:q
```

This will exit Vim and bring you back to the terminal.

Vim will now be the default editor for Git. *Nano* and *Emacs* are two other command line text editors that can be used. Pick your favorite. Nano is the most intuitive.

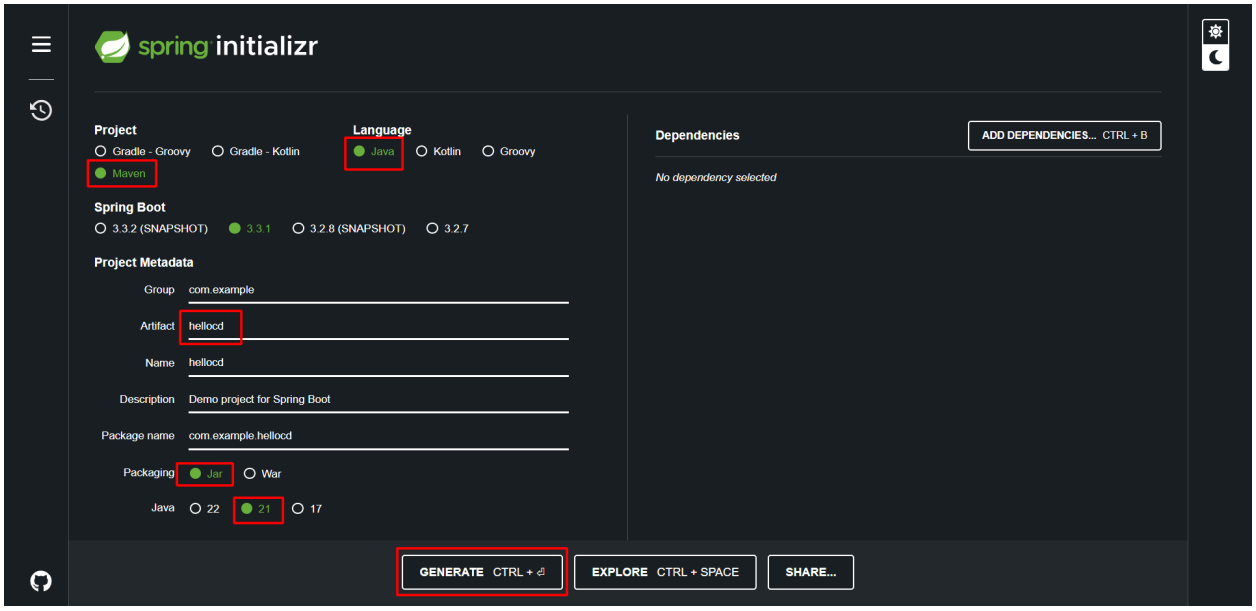
Creating a Sample Application

We need an application to use version control on.

We will guide you through creating a simple `hello-world` application using the Java-based **spring-boot** framework.

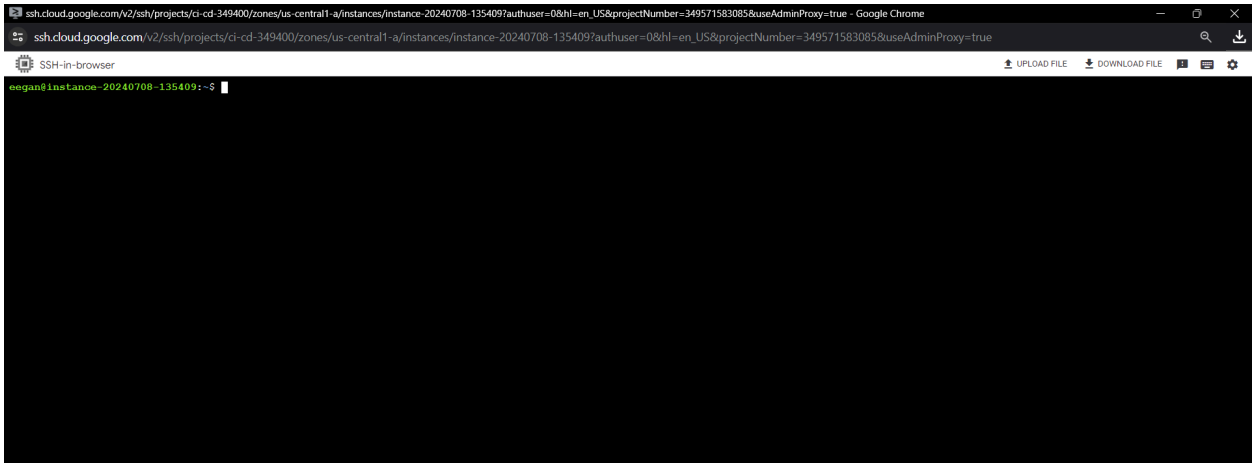
To create the application, visit https://start.spring.io/.

Be sure to select the **Maven Project**. Change your artifact name to `hellocd`. This can be anything you want, but we will change the artifact name to `hellocd`. Select **Java 21**. Click **Generate** to download your application.



After downloading the application code, move the **`.zip`** file to your local working directory and unzip that application.

If you are working on a Google Cloud VM, upload the file via the **UPLOAD FILE** link in the top right of the terminal.



Choose the file to upload and it will upload to the current working directory. Install the unzip program:

```
sudo apt install unzip
```

Unzip **`hellocd.zip`**:

```
unzip hellocd.zip
```

You will use this application for revision control operations.

Revision Control Basics

Now that you have a **hellocd** application downloaded and unzipped, you will use it to learn revision control operations. Enter the **hellocd/** directory.

```
cd hellocd
```

We will tell Git to make this directory a repository by *initializing* it. We do this with the following command from inside **hellocd/**:

```
git init
```

Now run:

```
git status
```

git status shows the status of all the files and directories in the repository. Untracked files and directories appear in red. You need to add these files so that Git starts tracking them. Use the following commands to start tracking the files in the **hellocd** project with Git:

```
git add pom.xml
```

```
git status
```

```
git commit
```

```
git status
```

```
git add src
```

```
git status
```

```
git add *
```

```
git commit mvnw
```

```
git status
```

```
git commit -am "adding files created with spring boot generator"
```

```
git log
```

git log --branches shows you the commit history and where each branch is at, while **git status** shows untracked files in your directory. Create one more file in your working directory

called `README.md`.

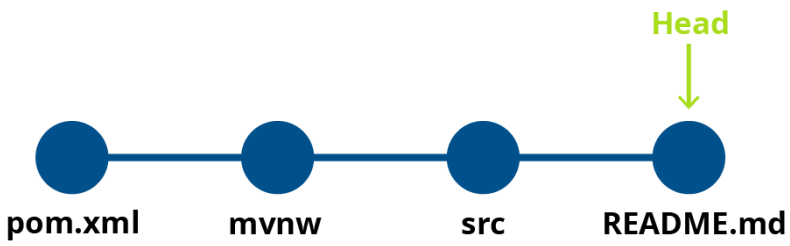
Note: the following command will start with whatever your chosen command line text editor was, nano, emacs, or vim:

```
vim README.md
```

Check your git status after that commit using `reset`:

```
git add README.md

git status

git reset README.md

git add README.md

git commit -am "adding README"
```

You have added and committed the files one by one, and this is the current state of your repository with each commit represented by a circle on the line:



Using Docker in Development

After creating a Java project based on Maven, we need to build and test it before deploying it into an environment. To do this, you will need a build environment. Instead of setting up and managing a build environment with Maven, Java, etc., you can leverage Docker's disposability feature.

You need to get the absolute path to the `hellocd` directory. From inside `hellocd` run:

```
pwd
```

The output will be the absolute path to `hellocd`. Be sure to use it in the following command in place of `/absolute/path/to/hellocd`.

Use the following command to run the container:

```
docker container run --rm -it -v /absolute/path/to/hellocd:/app
maven:3.9.8-eclipse-temurin-21-alpine sh
```

Running the above command gets you:

- A disposable container environment with Docker
- Created with the image **`maven:3.9.8-eclipse-temurin-21-alpine`**
- This container has build tools necessary to run a Java application, including Maven, Java, etc.
- Exiting this container will delete it, as we are using the **`--rm`** option.

You will see that your terminal prompt has switched to a **#** which indicates that you have a terminal inside the container. While inside the container, run the project with:

```
# mvn spring-boot:run -f app/pom.xml
```

You can see your libraries are stored in the **`/root/.m2/`** directory.

```
# ls /root/.m2/repository
```

```
ch  com  commons-io  commons-io  io  jakarta  javax  net  org
```

Type **exit** to return to your machine's terminal:

```
# exit
```

The container is immediately destroyed. You can reduce the time to download libraries by creating a volume which can then be mounted at this path.

```
docker volume create m2
```

```
m2
```

Run the following command:

```
docker container run --rm -it -v m2:/root/.m2 -v /path/to/hellocd:/app
maven:3.9.8-eclipse-temurin-21-alpine mvn spring-boot:run -f
```

```
/app/pom.xml
```

Run the same command again. You should notice the build is faster due to the Maven package being cached with the newly mounted volume.

Branching and Merging

Create a branch using the **`git branch`** command and switch to that branch using **`git checkout`**. The default branch is master. Whenever we need to work on another branch, we use the **`git checkout`** command. Let's run the following commands to see our branches and create and move to the **`webapp`** branch:

```
git branch --list
```

```
git log
```

```
git branch webapp
```

```
git branch --list
```

```
git checkout webapp
```

```
git branch --list
```

Instead of using a two-step process, you could have created and switched to the **`webapp`** branch with the following single command:

```
git checkout -b webapp
```

You can delete your branch using **`git branch -d`**. Before deleting the branch, you should switch to another:

```
git checkout master
```

```
git branch -d webapp
```

Now **`git branch`** will show that you only have the **`master`** branch. Since we want the **`webapp`** branch, we will create it and switch to it one more time:

```
git checkout -b webapp
```

Adding a New Feature by Branching Out

Now you are going to add new features to your application:

- For source code changes, visit the lfs 261 devops-repo and go to the **hellocd** directory. Copy **HellocdApplication.java.v1** code and replace the code in **HellocdApplication.java** which you will find in your **src/main/java/com/example/hellocd** directory.
- Copy **pom.xml.snippet1** from https://github.com/lftraining/devops-repo/blob/master/hellocd/pom.xml.snippet1 and paste it into the **pom.xml** file under the dependencies section between **<dependencies>** and **</dependencies>** before *or* after the dependencies you see present there.

Now you can check your git status. The result will be that those files you have changed are unstaged. We will add them, but first you can review the changes made using the following:

```
git diff
```

Continuously press **Enter** or hold **Enter** down to scroll to the bottom to see all changes. Press **q** to exit.

You can commit after **git add** or else directly commit by using **git commit -a**. The **-a** option, if you recall, means *'add all files with changes to the staging area'*. We will also use the **-m** option to add a message from the command line:

```
git commit -am "committing changes to pom.xml and
HellocdApplication.java"

git status
```

Now you can see the changes are in the new branch. The master still does not have any of those incorporated yet. This is the safer way of bringing your code to master. The following subsection will teach you how to bring these changes into the master.

Merging with Commit History

Previously you made some changes and committed to a new branch called **webapp**. It's now time to test the application.

Again, run the same **spring-boot** container command with the port mapped to **8080** on host:

```
docker container run --rm -it -v m2:/root/.m2 -v /path/to/hellocd:/app
-p 8080:8080 maven:3.9.8-eclipse-temurin-21-alpine mvn spring-boot:run
-f /app/pom.xml
```

Once the container is running, you can visit the application on `http://IPADDRESS:8080` or `http://localhost:8080`. When you visit your **webapp**, right now you will get an error due to some missing code in `HellocdApplication.java`. To fix this issue, copy the code inside `HellocdApplication.java.v2` and use that code to replace *all* the code inside your own `hellocd/src/main/java/com/example/hellocd/HellocdApplication.java` file. After replacing the snippet, run the following command to see your changes:

```
git diff
```

You will see that Git has made the added lines green. Continuously press **Enter** or hold **Enter** down to scroll to the bottom to see all changes. Press **q** to exit.

```
git commit -am "added missing annotations"
```

Again, run your **spring-boot** container and visit `localhost:8080`. You should now see **Hello World!** in your browser.

Change "Hello World!" to "Hello Continuous Delivery!" in `HellocdApplication.java`. Commit the change, then run your container. You will see **Hello Continuous Delivery!** in the browser.

```java
package com.example.hellocd;

import org.springframework.boot.*;
import org.springframework.boot.autoconfigure.*;
import org.springframework.web.bind.annotation.*;
import org.springframework.boot.SpringApplication;
import org.springframework.boot.autoconfigure.SpringBootApplication;

@SpringBootApplication
@RestController
@EnableAutoConfiguration
public class HellocdApplication {


    @RequestMapping("/")
    String home() {
        return "Hello Continuous Delivery!";
    }

    public static void main(String[] args) {
        SpringApplication.run(HellocdApplication.class, args);
    }

}
```

Now that the feature is added, it's time to incorporate these changes into the main branch by using **`git merge`**. Before you do so, make sure you switch to the main branch first:

```
git checkout master
```

```
git merge webapp
```

```
git log --branches
```

We can now delete our **`webapp`** branch using **`git branch -d`**:

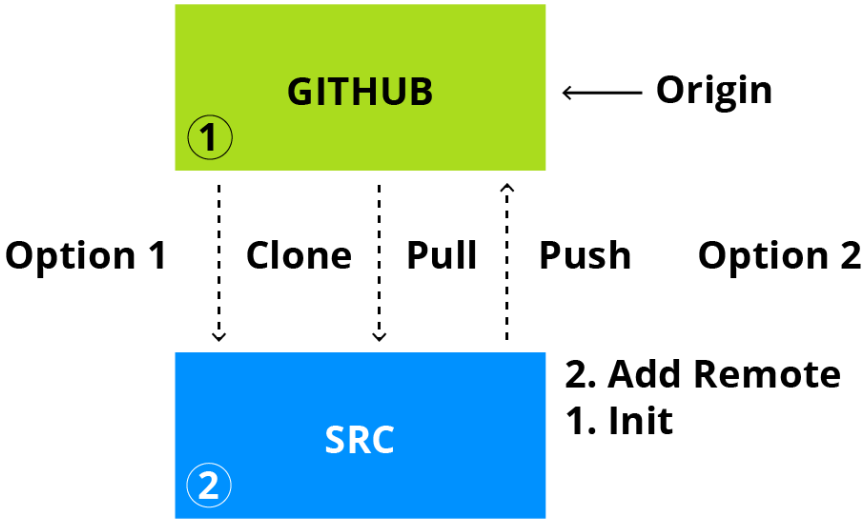
```
git branch -d webapp
```

Working with Remotes

You can collaborate and work with different branches, users, or central repositories by using *remotes*. Here, your central repository is GitHub.

There are two ways to go about this:

1. Create the repository on GitHub first.
    a. Clone the repository on your local machine.
2. Create the repository on your machine first.
    a. Create the repository on GitHub
    b. Tell your local repository to make the remote repository your GitHub repository



Before you start, you need to create an account on GitHub. Visit GitHub to create your account. While creating your account, use the free account option.

Once you create an account, create a new **`hellocd`** public repository. You have two ways to work with a repository. You could use an initialized repository or clone the repository from GitHub and make changes and push to your repository.

Here you have already initialized a repository. Now you need to add the newly created repository as origin by using the following command and push your application to that origin master:

```
git remote add origin https://github.com/xxxxx/hellocd.git
```

[Replace **xxxxx** with your GitHub user/org name, as per your repository URI]

```
git remote show
```

```
git remote show origin
```

```
git push origin master
```

Once you push to the origin master, you can see your code in the repository with the commit that you have changed.

Resolving Conflicts

When you are collaborating with others, conflicts can happen. Git provides you with various options to resolve them.

Add the line `server.port=80` in `src/main/resource/application.properties` while you are on the main branch, commit and push:

```
git diff

git commit -am "added server port 80"

git push origin master
```

Creating a Conflict

To resolve a conflict, we first have to create one. To do that, you will create two branches and update the same file with different content in each branch. The following sequence of commands will help you do that.

You have the option to work in pairs. The commands are differentiated between *user1* and *user2*. Make sure you are working with the same repository in case you are working in pairs. If you cannot find a partner, go ahead and run both blocks of commands from the same workspace.

user1: Use the following code:

```
git checkout -b user1
```

Set the value of `server.port` to `8080` in `src/main/resource/application.properties`:

```
git diff

git commit -am "this should run on port 8080"

git push origin user1
```

user2: Use the following code:

```
git checkout -b user2
```

Set the value of `server.port` to `8081` in `src/main/resource/application.properties`:

```
git diff

git commit -am "this should run on port 8081"

git push origin user2
```

Once you do the above, switch to the main branch and try to merge the branches you just updated, simultaneously. Each will run into a conflict.

user1:

```
git checkout master

git pull origin user2

git log --branches

git push origin master
```

user2:

```
git checkout master

git pull origin user1

git log --branches

git push origin master
```

You should get into a conflict here. Use `git log` to check the details.

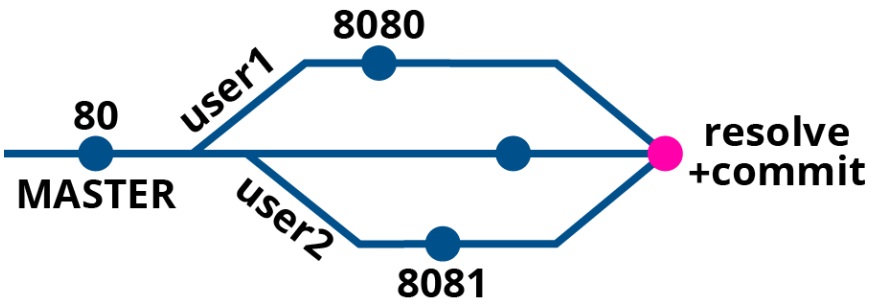
Manually Resolving a Conflict

You can resolve a conflict manually by editing the file in conflict. In this example, you can pick one value for `server.port` and keep that line in the file. Remove everything else including the lines starting with **<<<<<<<<** and **>>>>>>>>>**. Once you do so, commit the changes:

```
git commit -am "resolved merge conflict"

git push origin master
```

Validate by examining the commit history:

```
git log --branches
```



Once you complete this, delete your user1 and user2 branches by using the following commands:

```
git branch -d user1
```

```
git branch -d user2
```

```
git push origin --delete user1
```

```
git push origin --delete user2
```

Learning to Undo

It's common to add changes to the commit history and later wish you could have taken those back. At times, mistakes or bugs you detect in your feature branches do not need to be reflected in the commit history. There are times when you may wish to unstage a file. Git offers the **`reset`** command with its options to achieve this.

Let’s add a change that we will undo later:

```
git checkout -b config
```

```
git branch
```

Update **`src/main/resource/application.properties`** with **`server.port=9000`**:

```
git status
```

```
git add src/main/resource/application.properties
```

```
git status
```

The file has now been staged. To unstage the same:

```
git reset src/main/resource/application.properties
```

```
git status
```

```
git diff
```

```
git commit -am "changed port to 9000"
```

```
git log
```

```
git push origin config
```

You have not only added it to a commit history, but also pushed the change to the remote.

Let's say that you have realized that `9000` should really be `8080`.

Try using the following command:

```
git reset HEAD~1
```

Note: that is HEAD *tilda* 1. Don't mistake the tilda for a dash, or it won't work. This should revert the last commit and point the **`HEAD`** (the tip of the Git repository) to the previous commit. You could use **`HEAD~2`**, **`HEAD~3`** to shift the **`HEAD`** back by two/three commits, respectively. You could optionally use the commit ID to shift **`HEAD`** to a specific commit.

What you did above was a mixed reset. This means the undo was done for the commit history only. You would still see the files in the staging area, and the current working tree being unchanged.

You can undo it all the way (this is a destructive process) by doing a hard reset:

```
git reset --hard HEAD~1
```

Once you reset, if you try to push the changes to remote, it should give you an error. To undo changes to remote, use the **`force`** option:

```
git push origin config -f
```

Revert vs Reset

`reset` is useful when working on feature/personal branches. However, when you have a collaborative workflow with common branches such as trunk/mainline/master, resetting changes on common branches can leave everyone else confused and in an inconsistent state.

This is because **reset** wipes out the commits to undo changes. A cleaner solution in such cases is to use **git revert** instead, which undoes the changes by creating a new commit that is then part of the commit history, leaving everyone in sync.

To learn how **revert** works, let's first update a file and commit it.

Use the **config2** branch and file and commit the changes in the feature branch, bring those changes to the main branch using the following commands:

```
git checkout -b config2
```

Update **src/main/resource/application.properties** with **service.port=7000**:

```
git diff
```

```
git commit -am "run on port 7000"
```

```
git push origin config2
```

```
git checkout master
```

```
git pull origin config2
```

```
git push origin master
```

Now that you have incorporated these changes to the main branch, it's time to revert:

```
git log
```

```
git revert HEAD
```

or

```
git revert 5080dcc9d13ac920b5867891166a
```

Where **5080dcc9d13ac920b5867891166a** is the previous commit ID that you would want to revert.

Once you revert, you need to sync the changes in the main branch with remote by using the following command:

```
git log
```

```
git push origin master
```

Once you sync the changes, it will show the changes to your co-developer and delete your **config2** branch after **git revert**:

Go ahead and delete the branch:

```
git branch -d config2
```

```
git push origin :config2
```

Working with GitHub

Next, create a new repository to keep a journal. On GitHub, create a repository and add a description and `init` with a `README.md` file with the license for your public repository.

Once you create the repository, clone it locally by using the following command and add your skills in a file, then push to your origin. Create a file inside the repository called `skills.md`:

```
git clone https://github.com/yourUsername/skills-journal.git
```

Create a file inside the `skills.md` repository then commit it:

```
git commit -am "added skills"
```

```
git remote show
```

```
git remote show origin
```

```
git push origin master
```

If you like, you can create more files, commit, and push them to your remote repository on GitHub.

Summary

In summary, we initialized a local Git repository on our machine, created a Spring Boot application within that repository, made changes, and tracked those changes using Git. We ran a Java and Maven container so that we would not have to load Maven on our local machine. This container ran our SpringBoot application. We connected our local git repository to a remote git repository on GitHub. Finally, we learned how to handle conflicts when merging branches both locally and remotely.

Lab 4. Setting Up Continuous Integration with Jenkins

By the end of this lab exercise, you should be able to:

- Set up Jenkins using Docker
- Take a walkthrough of the Jenkins web interface and essential configurations and start creating freestyle and maven jobs
- Integrate with tools such as Node.js and Maven
- Integrate with GitHub and set up build triggers
- Set up pipelines which run automated builds and unit tests

Install Docker Compose

Follow the directions at https://docs.docker.com/compose/install/ to install Docker Compose on your machine.

Set Up Jenkins with Docker

You will learn how to set up Jenkins using Docker. Docker must be installed before this lab.

You will be running a Jenkins container on your Docker host by using the Jenkins image with version **`jenkins/jenkins:2.492.3-lts-jdk21`**. Use the following commands to clone the **`devops-repo`** directory and launch the Jenkins container:

```
git clone https://github.com/lftraining/devops-repo.git
```

```
cd devops-repo/setup
```

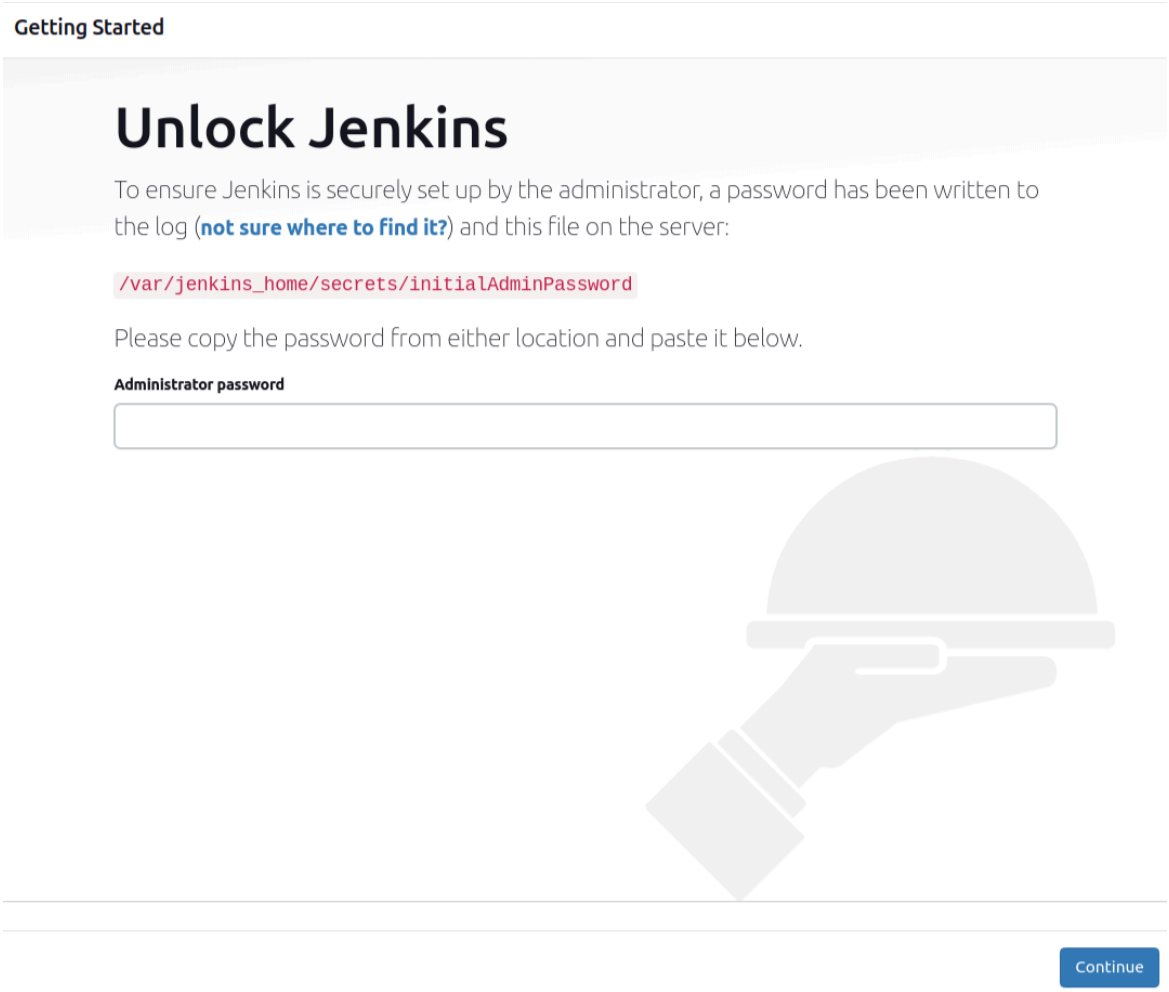
Inside the **`devops-repo/setup`** directory is the **`docker-compose.yml`** and the Dockerfile

that we will be working with.

```
docker compose build
```

```
docker compose up -d
```

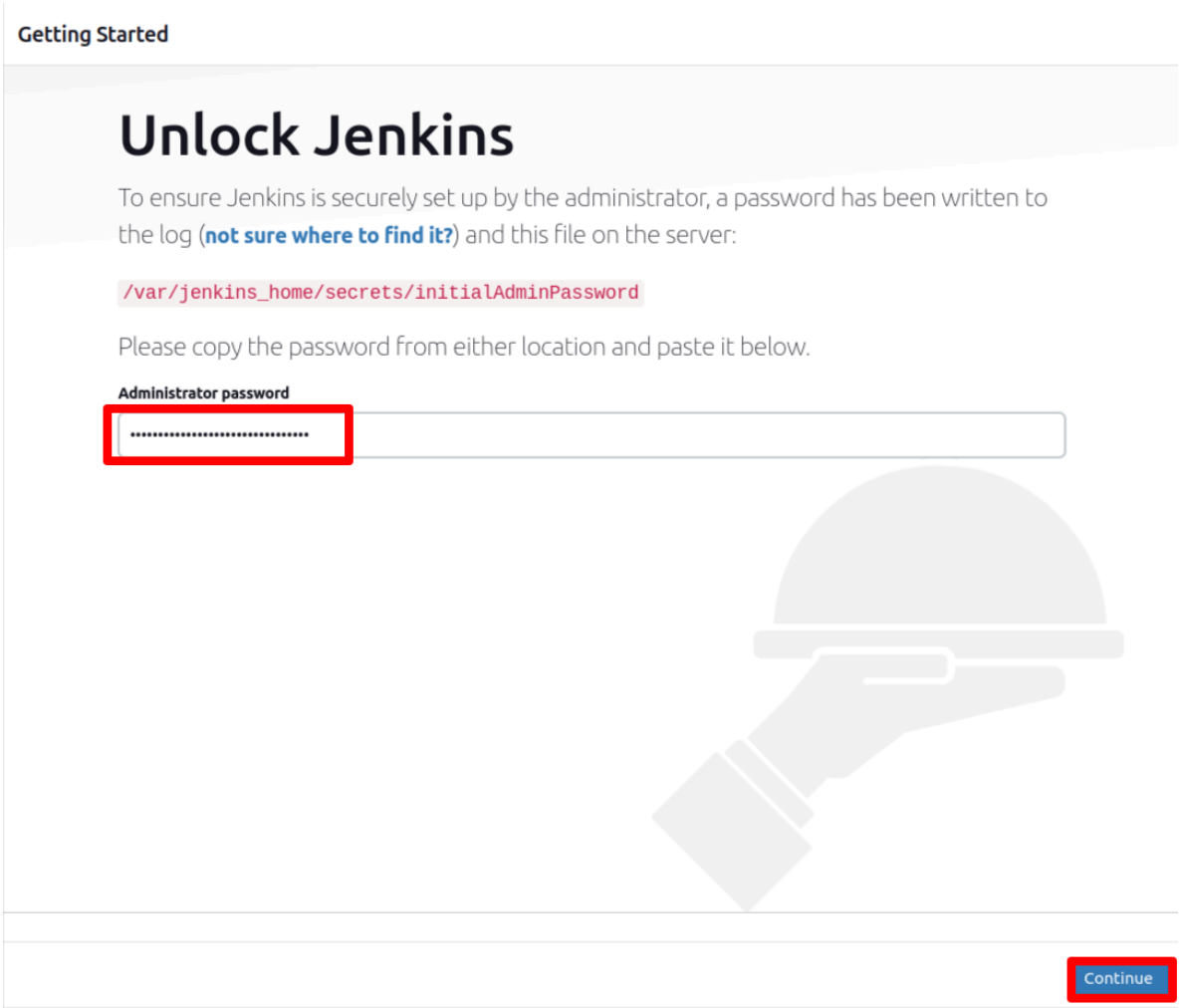
Access the Jenkins UI by browsing to **`http://IPADDRESS:8080`**. In this case, it will most likely be **`http://localhost:8080`** if you are on your own machine. If you are in the cloud, you will need to find the public IP of your cloud machine.



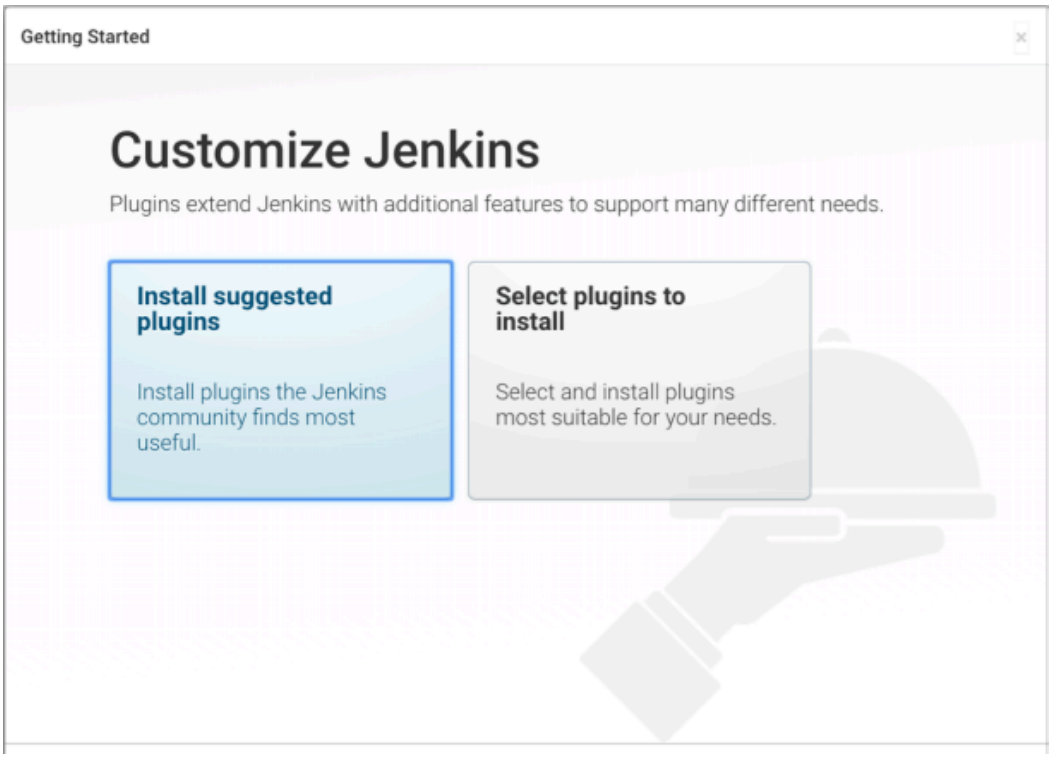
To fetch the **`initialAdminPassword`** use the following command:

```
docker exec -it setup-docker-1 cat /var/jenkins_home/secrets/initialAdminPassword
```

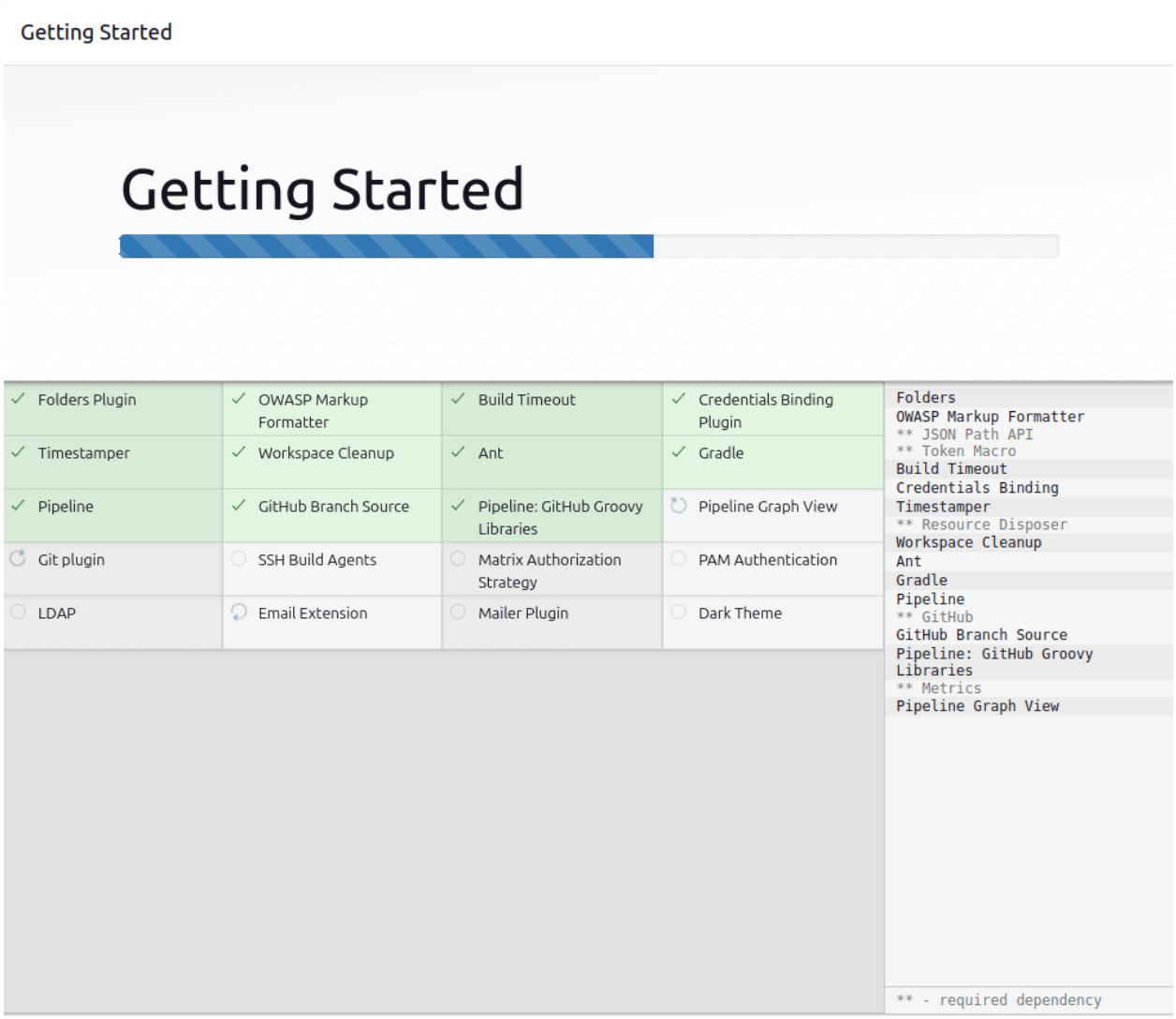
The output will be the initial Jenkins password. Paste it into the Jenkins UI to unlock and click **Continue**.



In the next step, choose **Install suggested plugins** to configure the default plugins automatically.



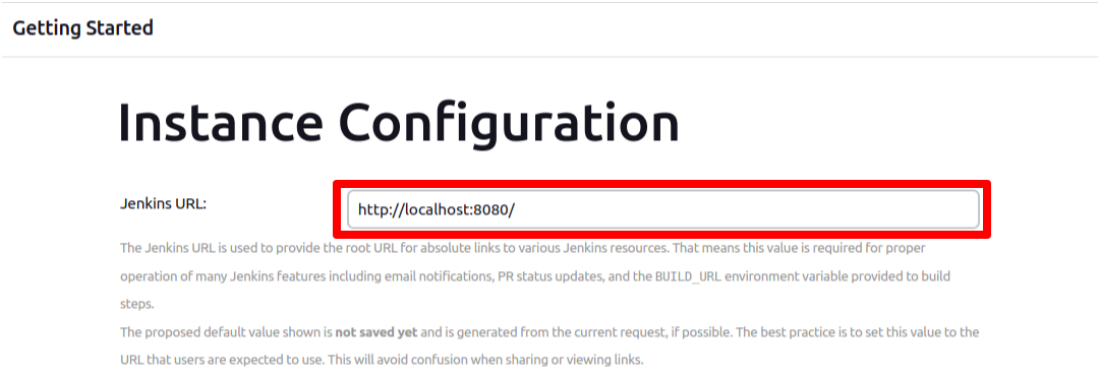
You will be able to observe the progress of the plugin installation process as follows:



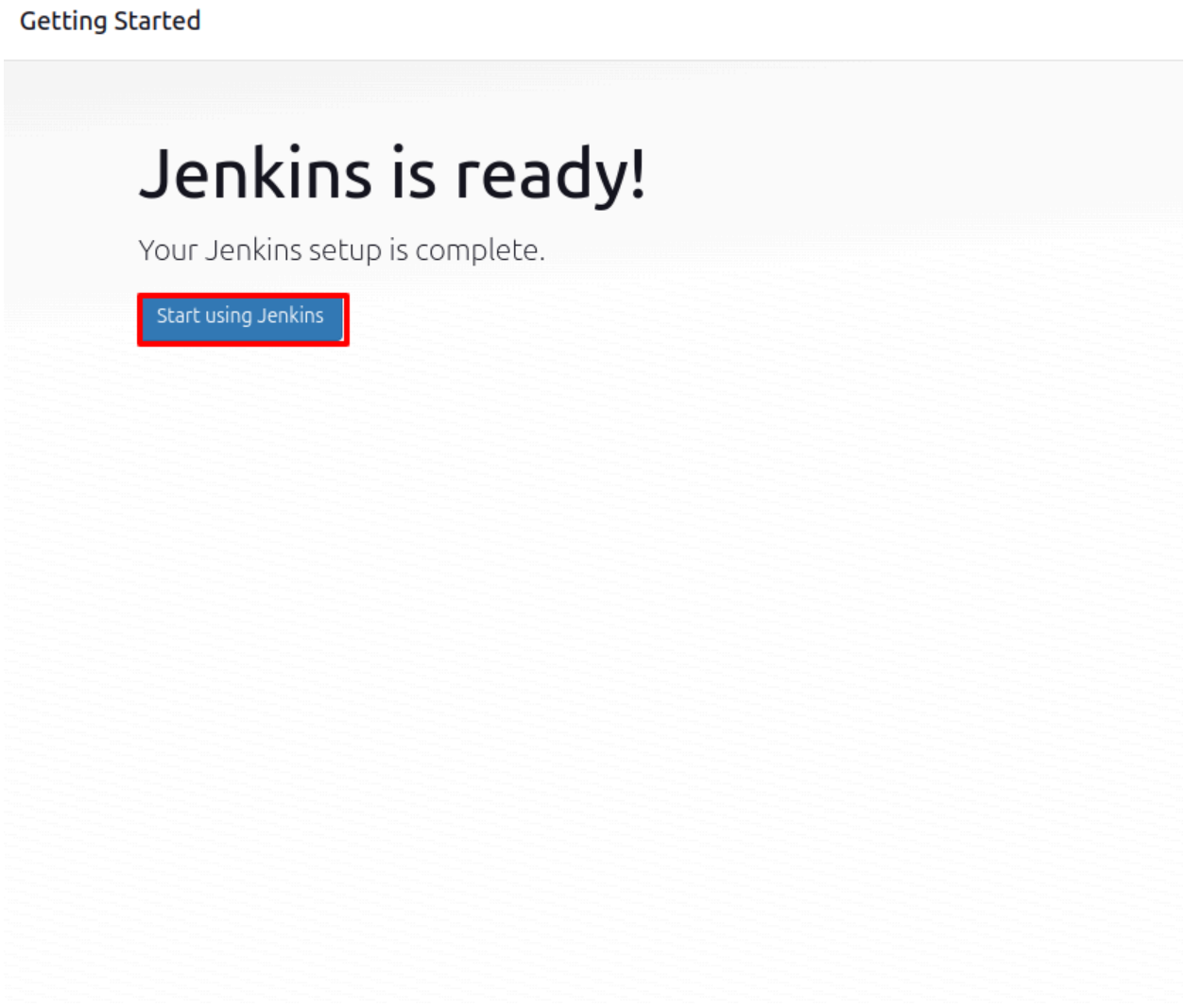
Once the plugins are installed, create the admin user using the form presented. Fill out the page and click **Save and Continue**. You can use a username and password of your choice

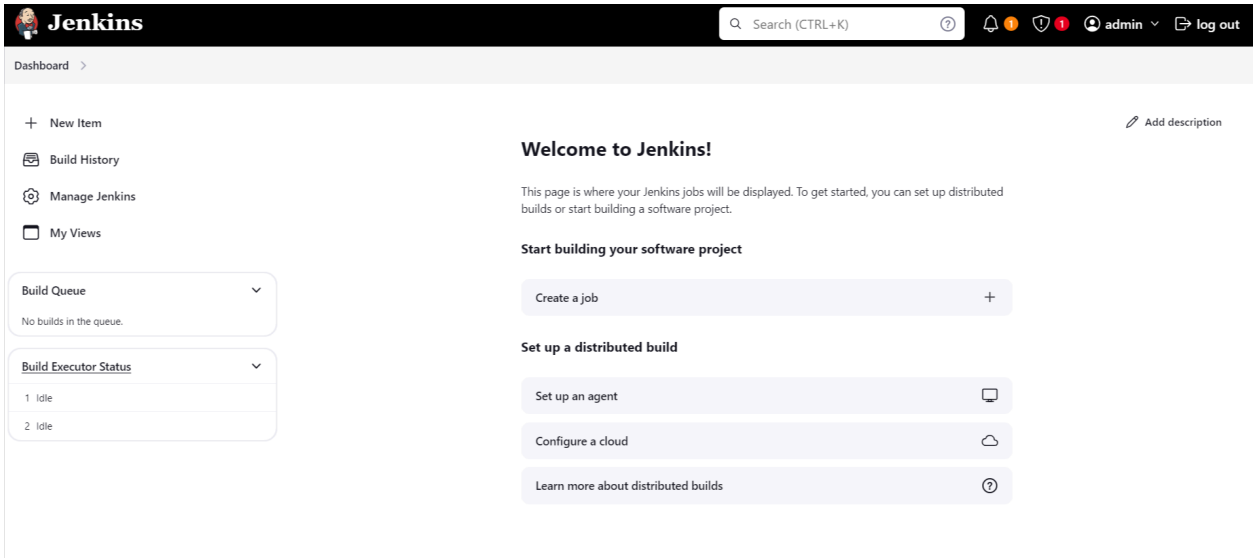
Getting Started

On the **Instance Configuration** page, the URL will depend on whether you are on a local or cloud machine. The default should be fine for our purposes. Click **Save and Finish**.



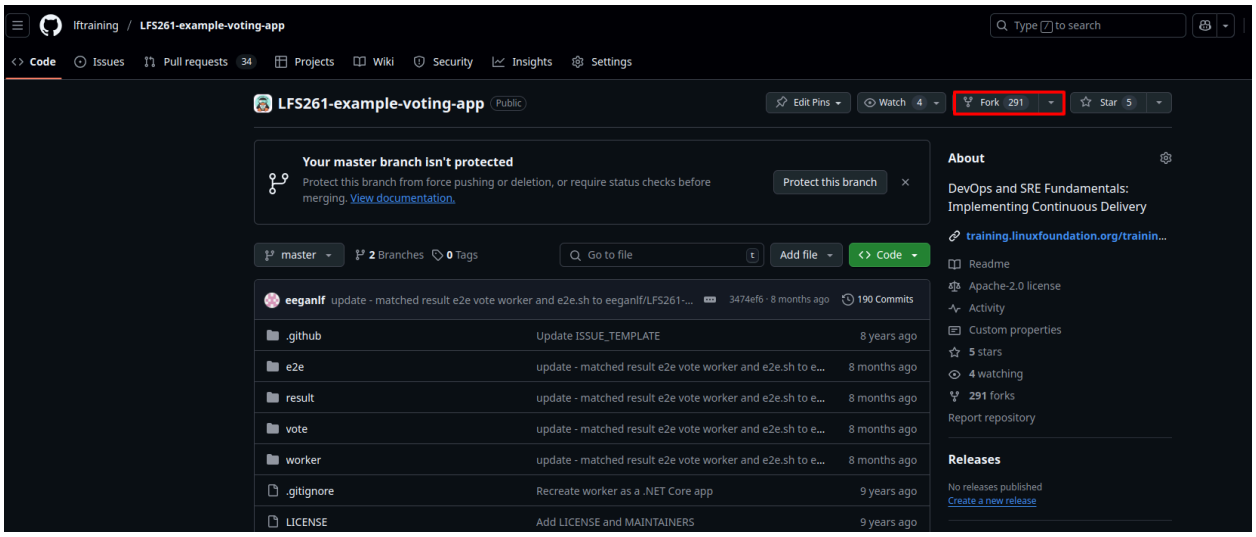
You should see a confirmation page. Click **Start using Jenkins** or **Restart**.





Fork the Voting App

Visit [example-voting-app on GitHub] and fork the repository onto your Git account.



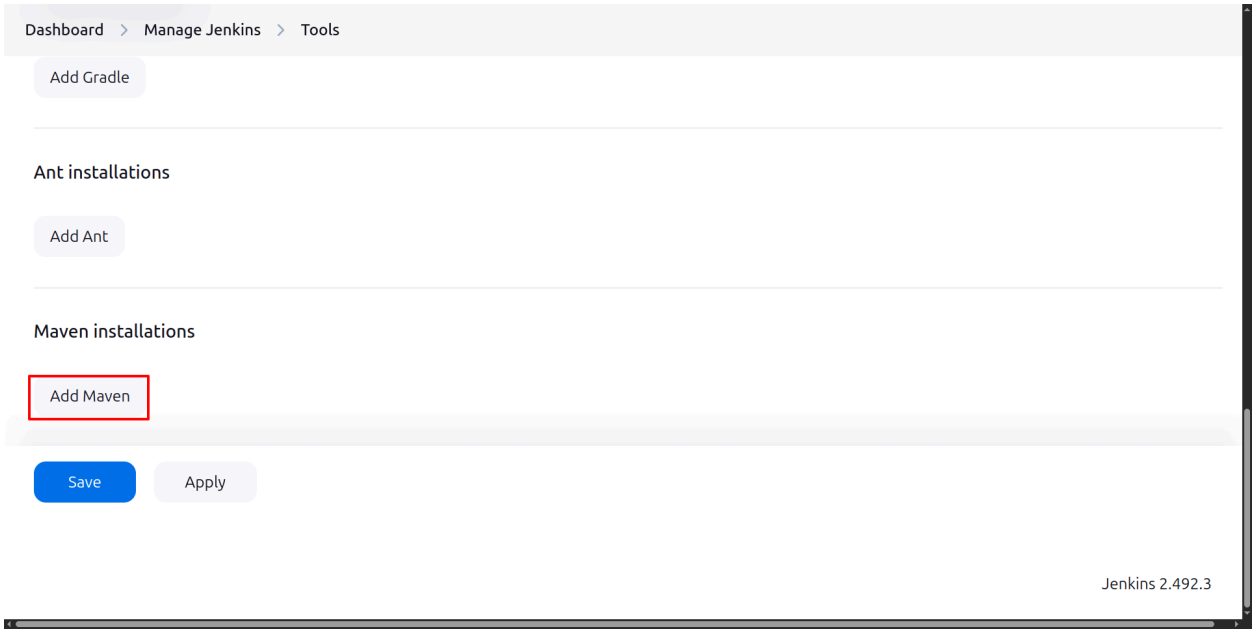
Clone the repository onto your own machine.

Configuring a Maven Build Job

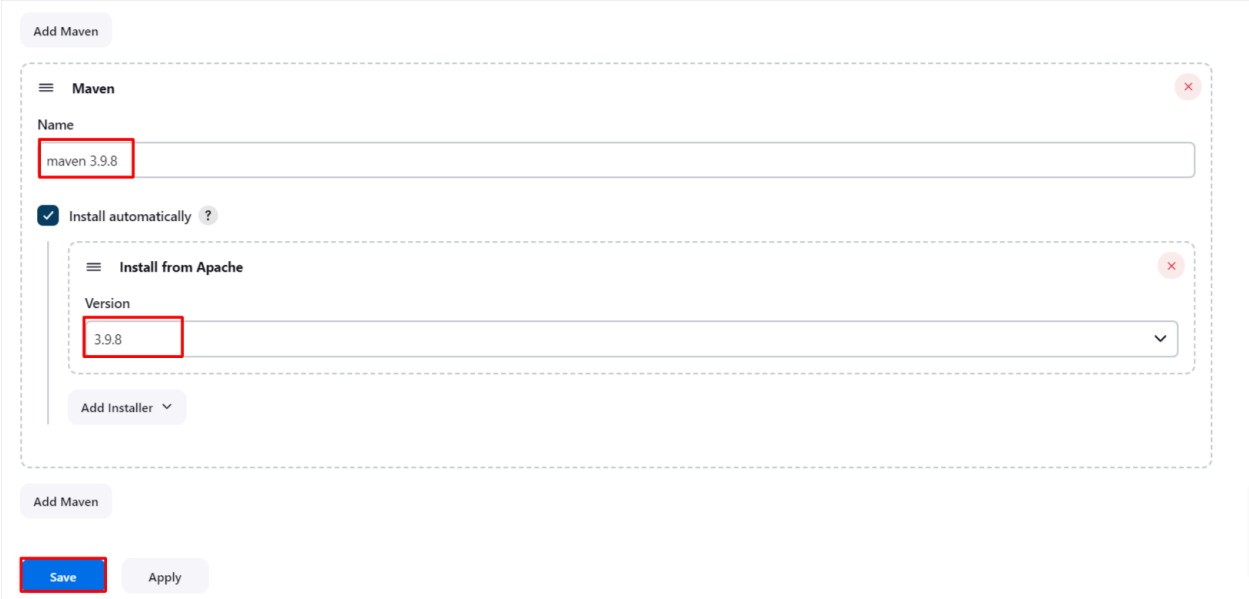
We went over a simple **`job-01`** in Chapter 6. Now you will build the **`worker`** application as part of the **`example-voting-app`** project. This is a Java application that uses Maven as a build tool.

First we will configure a Maven build job.

Go to **Manage Jenkins > Tools** and, under the **Maven** section, click **Add Maven**.

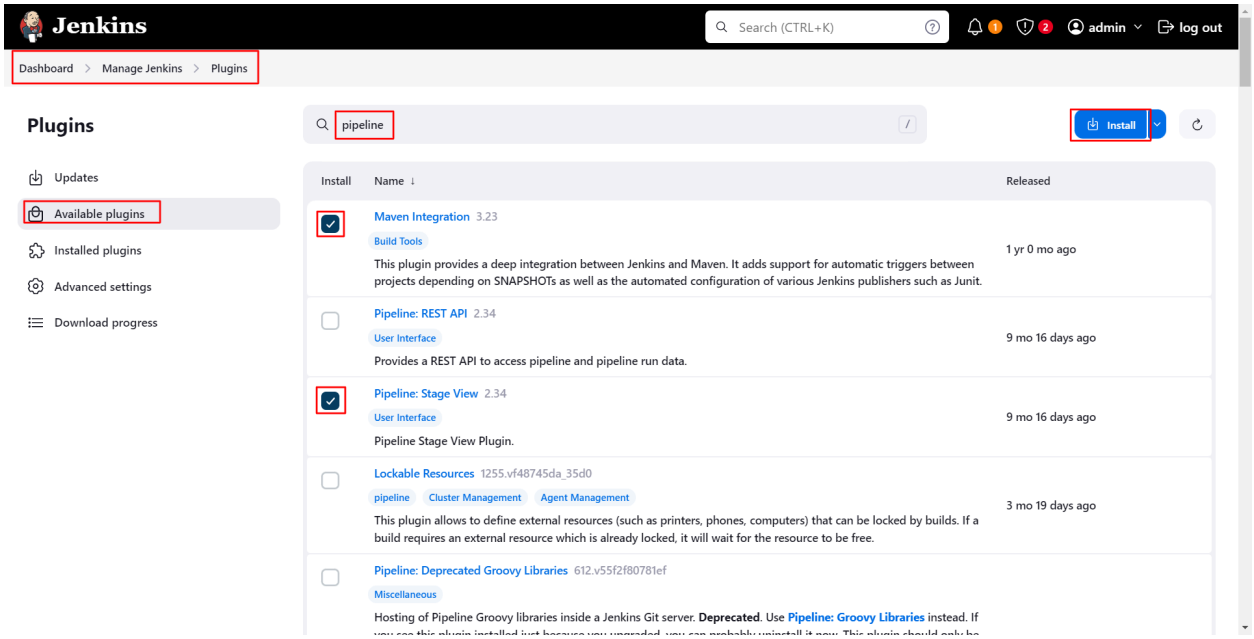


Paste `maven 3.9.8` into the name box and select maven version **3.9.8** from the **Version** dropdown menu under **Install from Apache**. Save the changes:

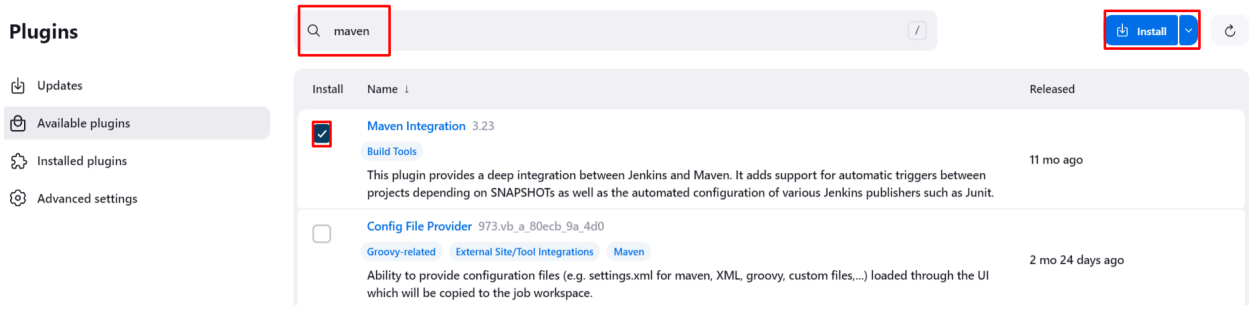


***NOTE**: Remember to use the exact name in this screenshot. This is the name you are going to use to reference the Maven installation in your Jenkinsfile later. If you provide a different name, be aware of it in future labs.*

Install the Maven integration plugin. Go to **Manage Jenkins > Plugins > Available plugins**, search for **Maven Integration** and **Pipeline: Stage View** plugin and install them:



.



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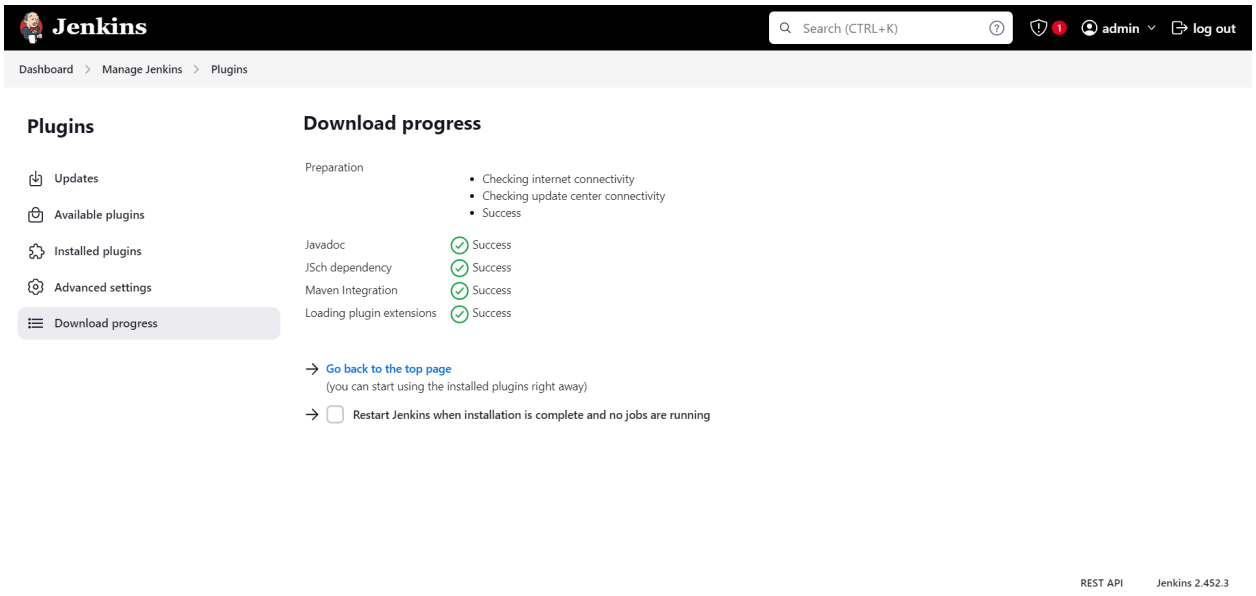
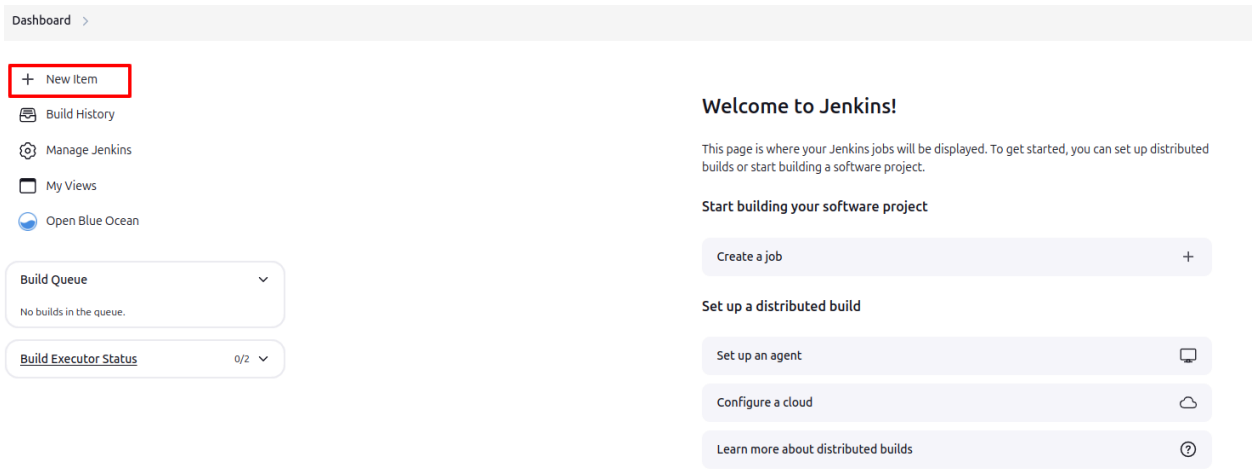
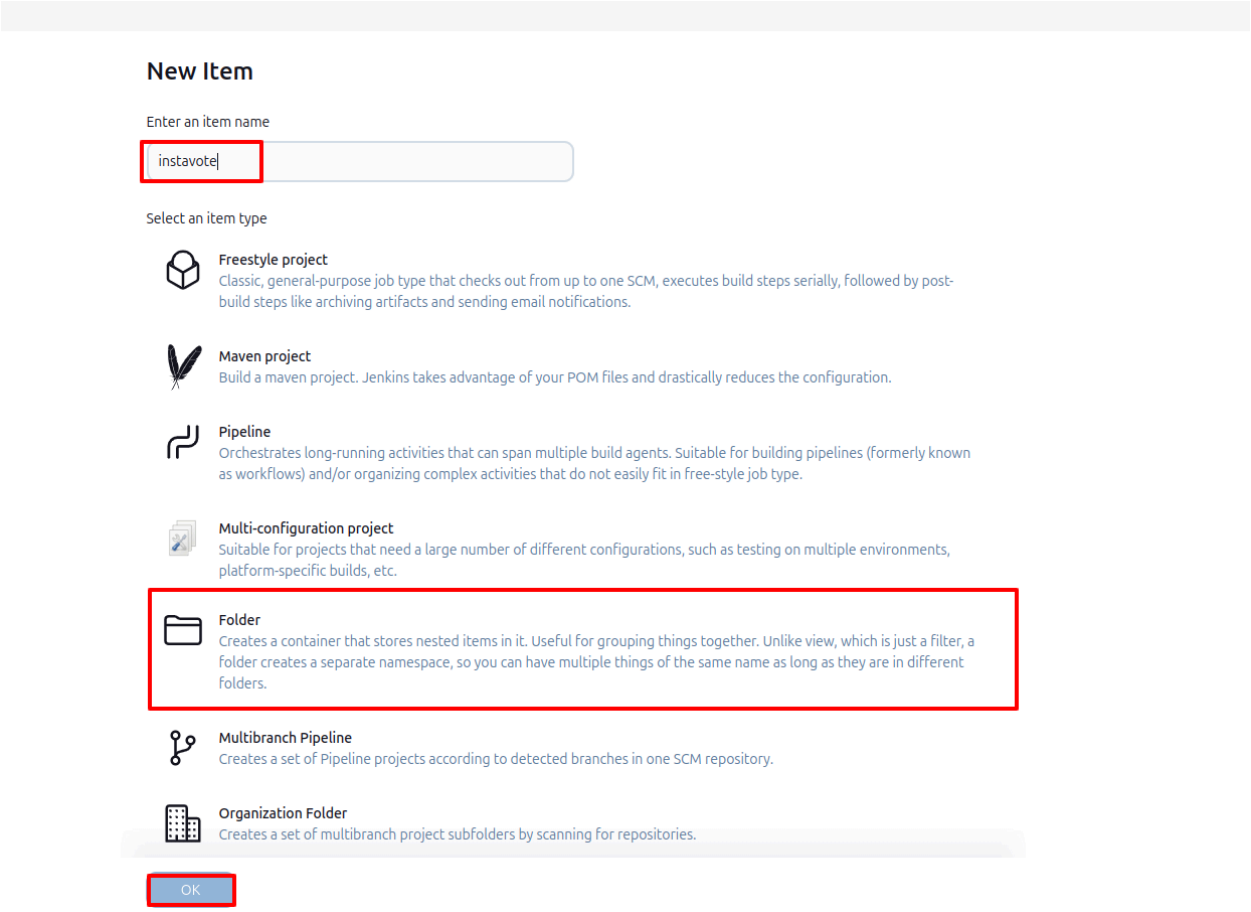
Click **Dashboard** in the top left of the page to go back to the home page.



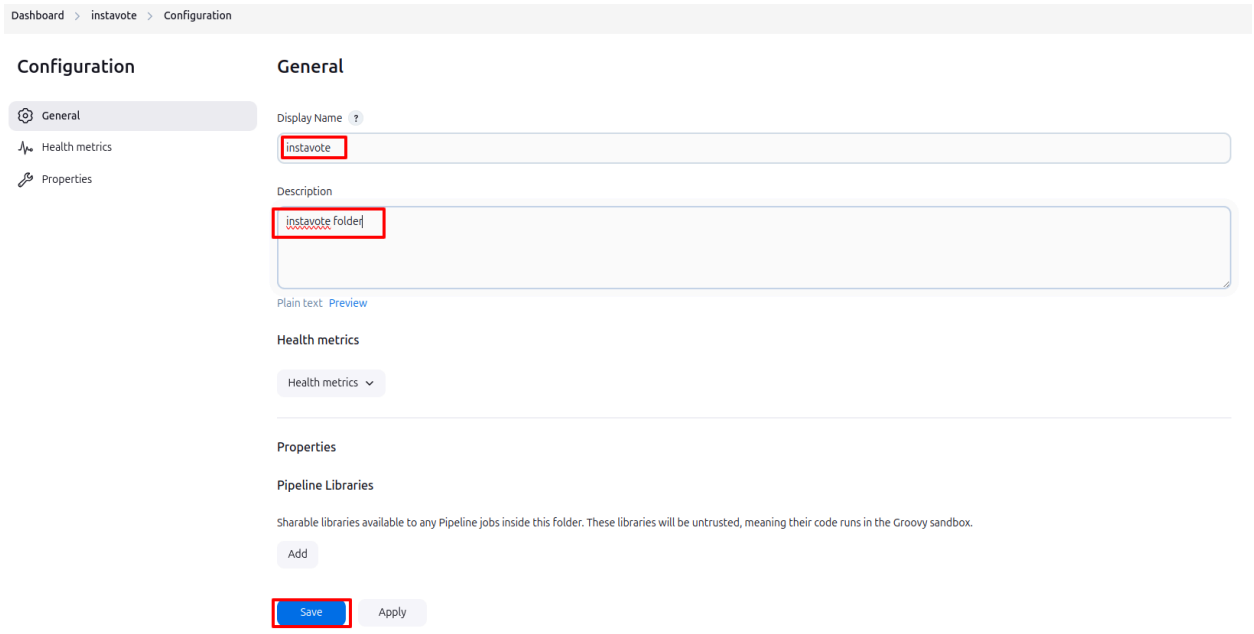
Create an `instavote` folder for your project. To do this, click **New item**:



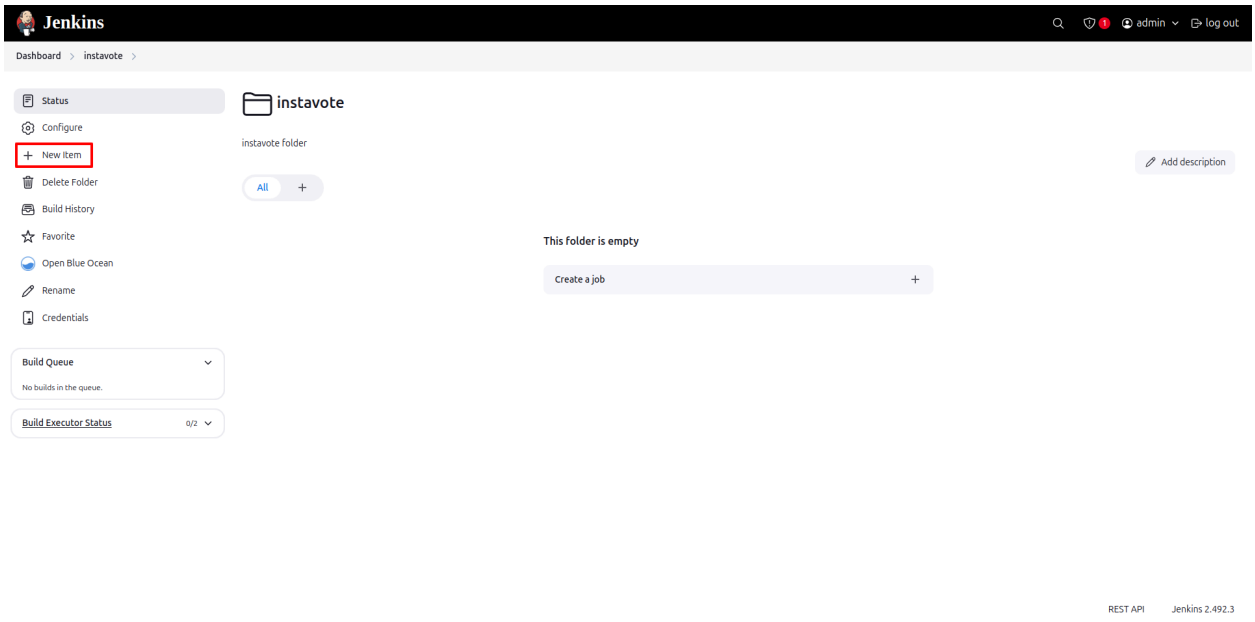
On the item creation page, enter the name as “instavote” and select the type as **Folder**. Click **OK**:



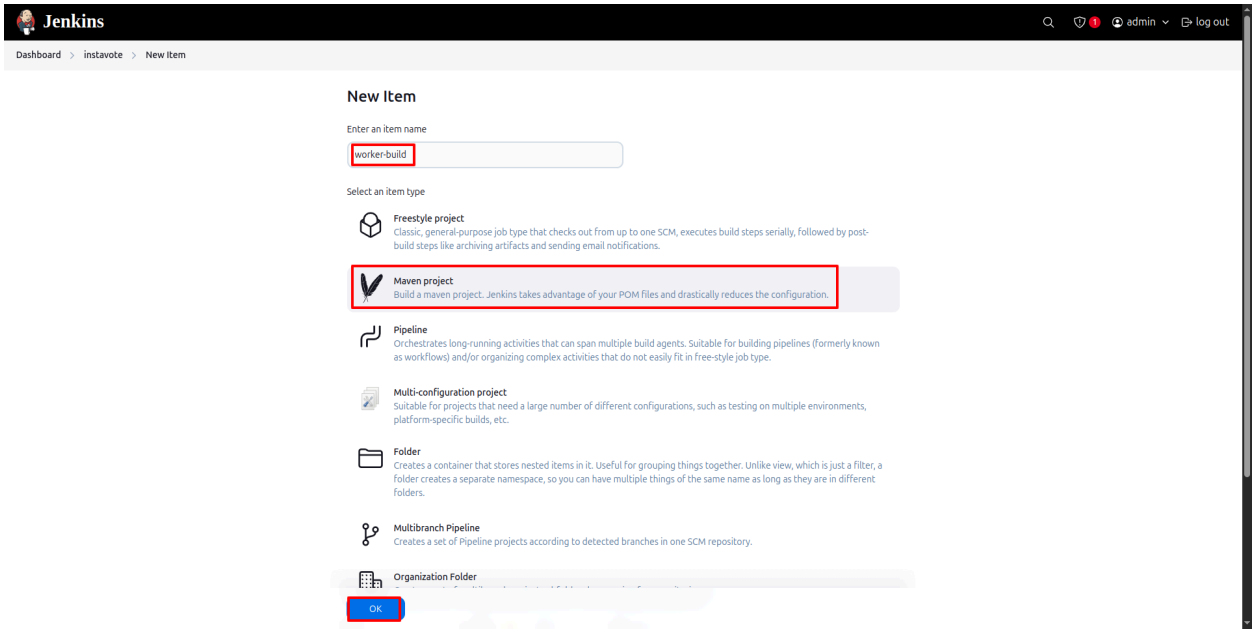
On the configuration page that appears, fill out the required details as follows and **Save**:



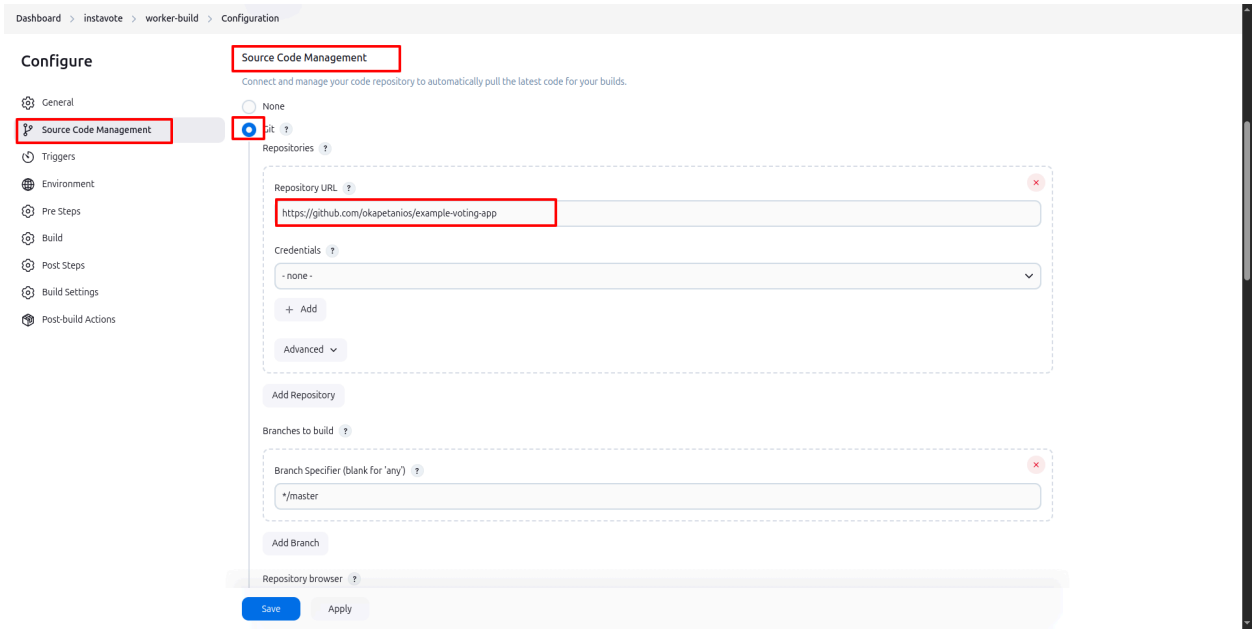
Inside the `instavote` folder, create a new item:



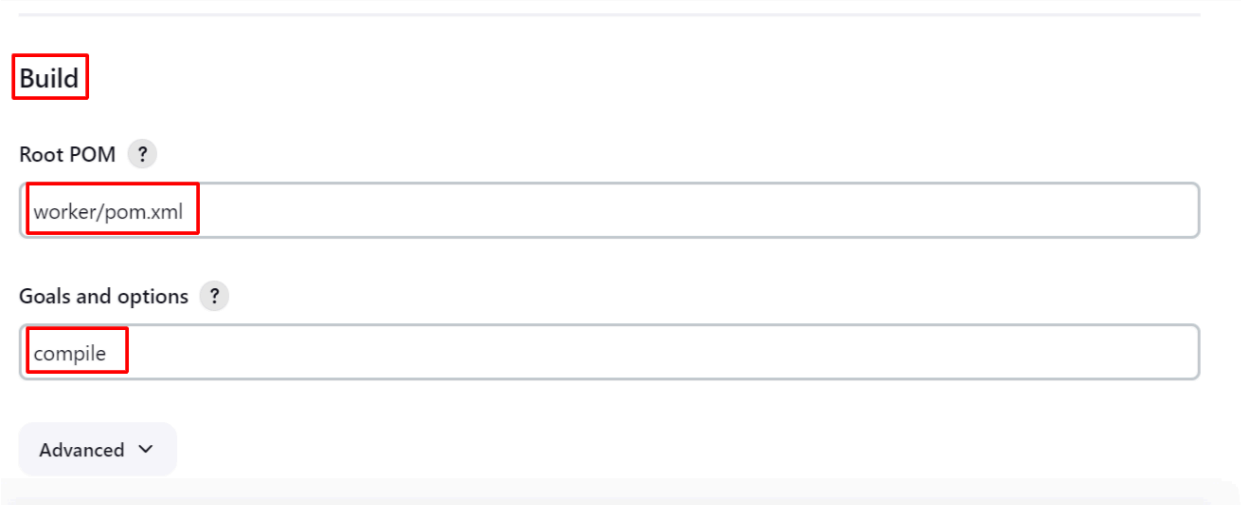
Select **Maven project** as the project type. Name the job **`worker-build`** and click **OK**:



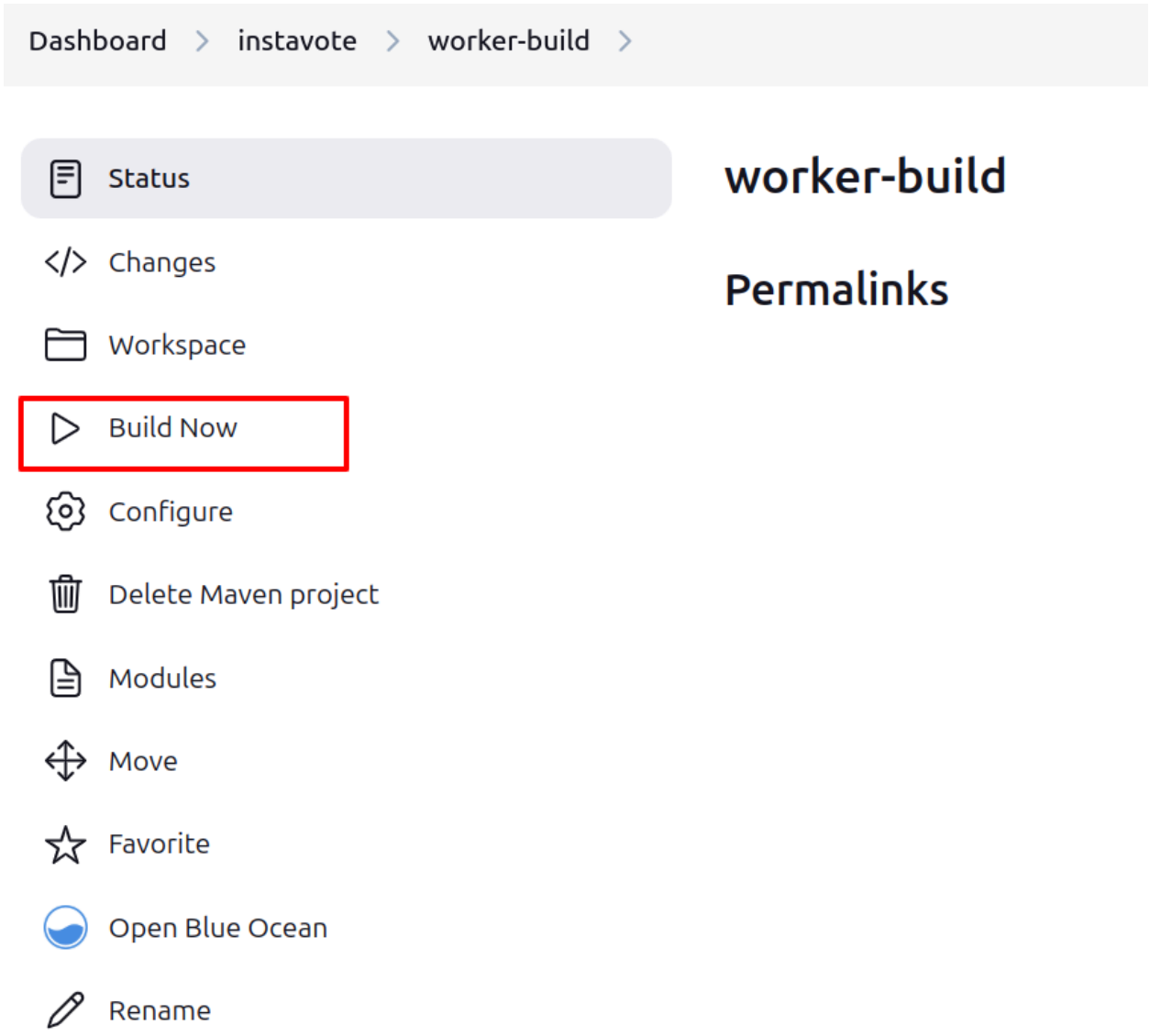
The **Configuration** page will appear. Scroll to the **Source Code Management** section and check the **Git** option. Provide the URL to your **`example-voting-app`** repository that you forked earlier.



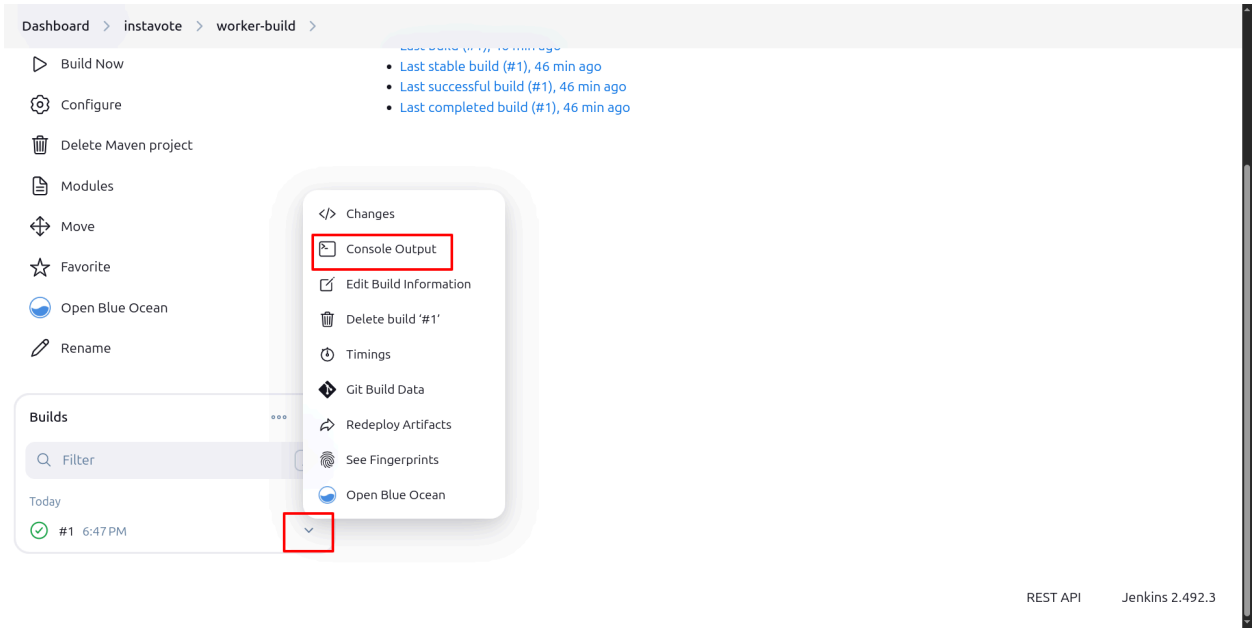
Go to the **Build** section. Provide the path to `pom.xml`, which is in the `worker` subdirectory of the repo, i.e. `worker/pom.xml`. Type or paste **compile** into the **Goals and options** box.



Save the job and build.



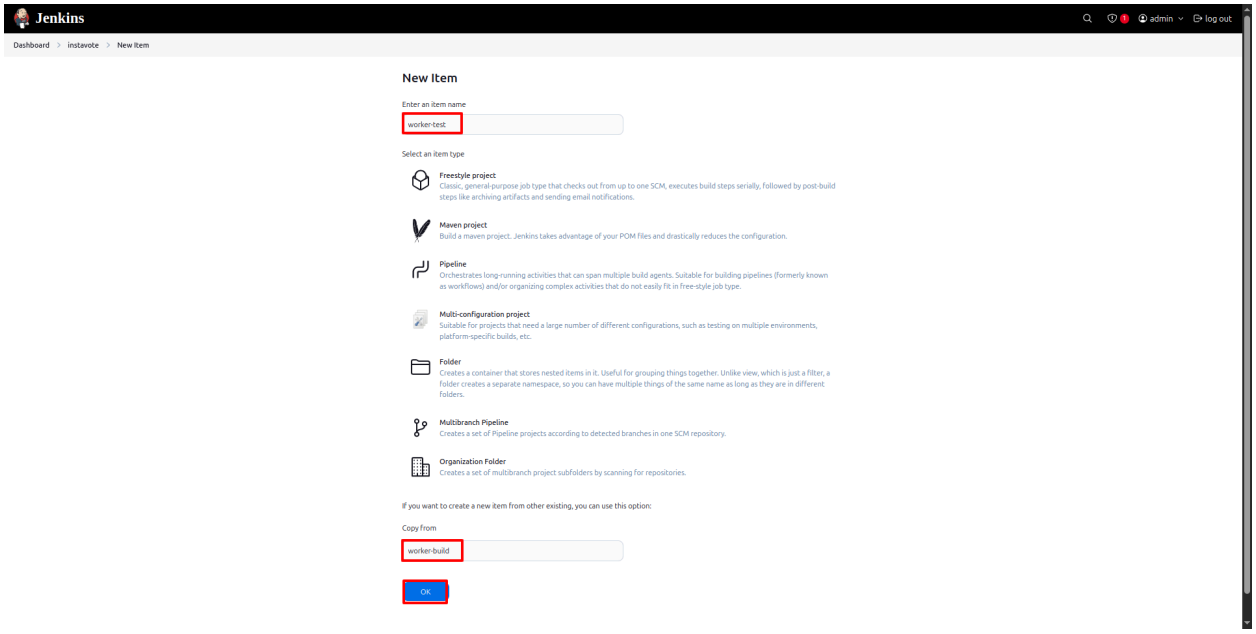
Observe the job status, console output, etc.



Adding Unit Test and Packaging Jobs

You will now add test and package jobs for the worker application.

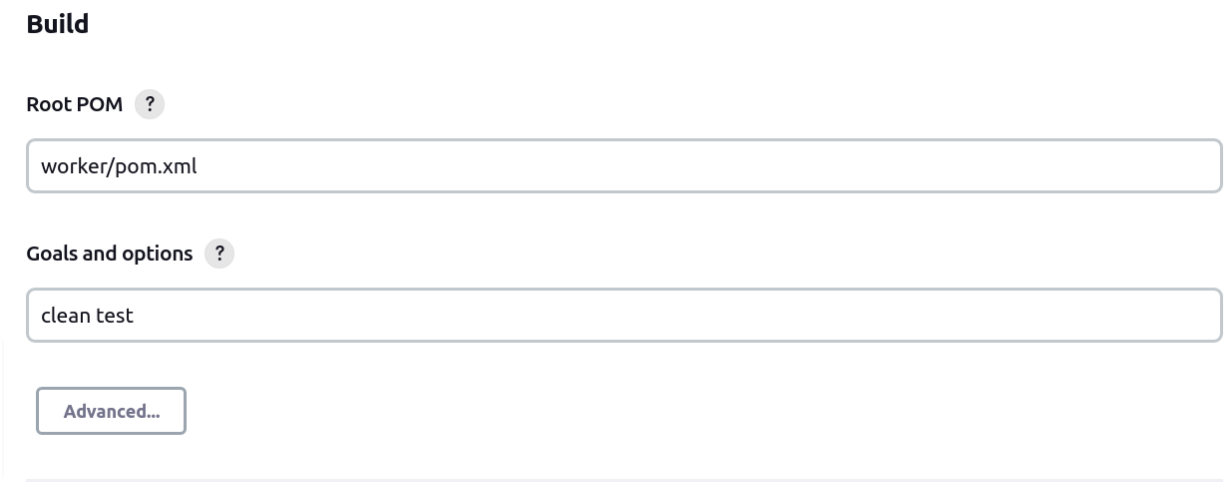
You need to create one more job in the **`instavote`** folder and name it “worker-test”. You can copy the **`worker-build`** job.



Follow these steps to complete the configuration.

In the **`worker-test`** job, change your description to “test worker java app”. The source code management repository is the same.

Under the **Build** section, change the **Goals and options** field to “clean test” and leave the rest. Save the job and build.

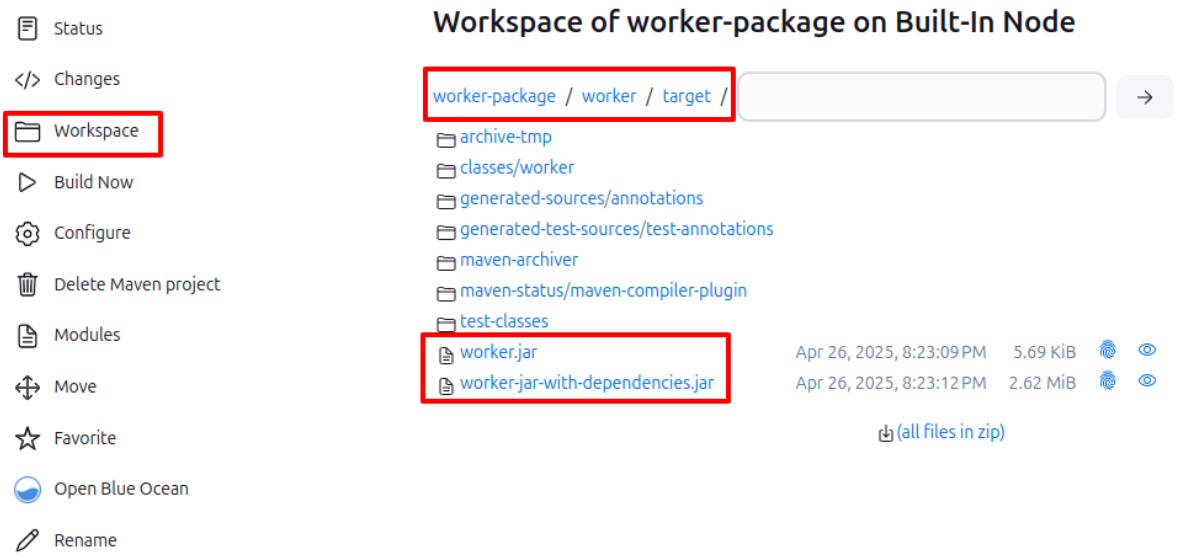


The next job will be **`worker-package`**. This will compile the application and then generate the **`.jar`** file. Create a job in the same folder named “worker-package”, copying the **`worker-test`** or the **`worker-build`** job.

Update the description to “package worker java app, create jar”. The only change in the configuration is in the Build step.

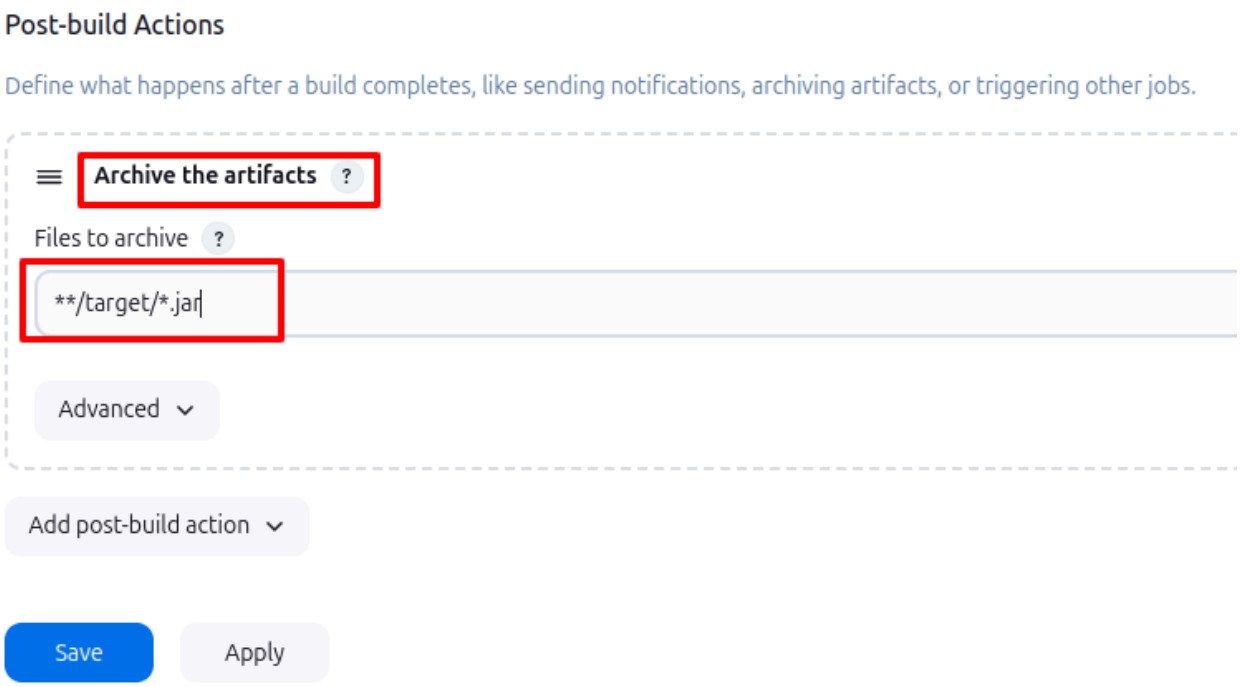
In the **Build** section for the package job, change the goal to “package -DskipTests”. Save the changes and build.

After the build is successful, you can see the `.jar` files created in the workspace under the `worker/target/` directory. You can verify your workspace by comparing it to the screenshot below.



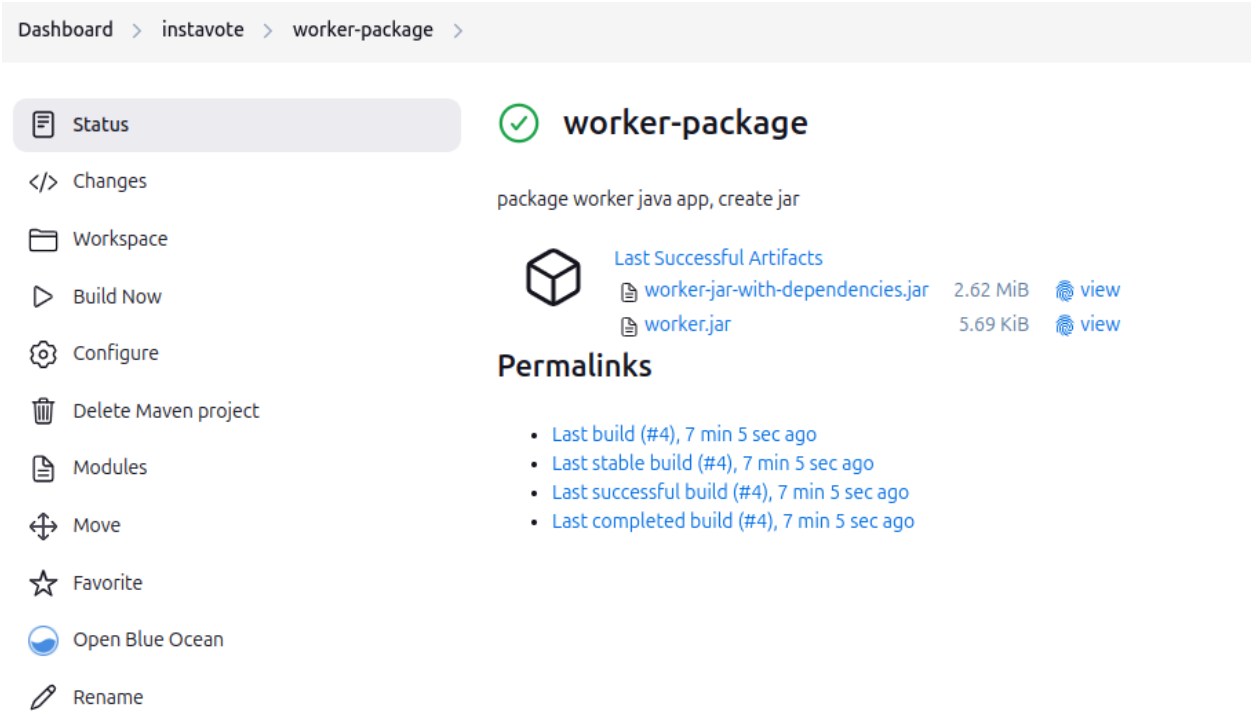
Click the **Configure** option in the left panel.

From the post-build actions, choose **Archive the artifacts** and provide the path `**/target/*.jar` to store the `.jar` file.



Save the changes and build the job.

Once the build is successful, check the project page to find your artifacts there.



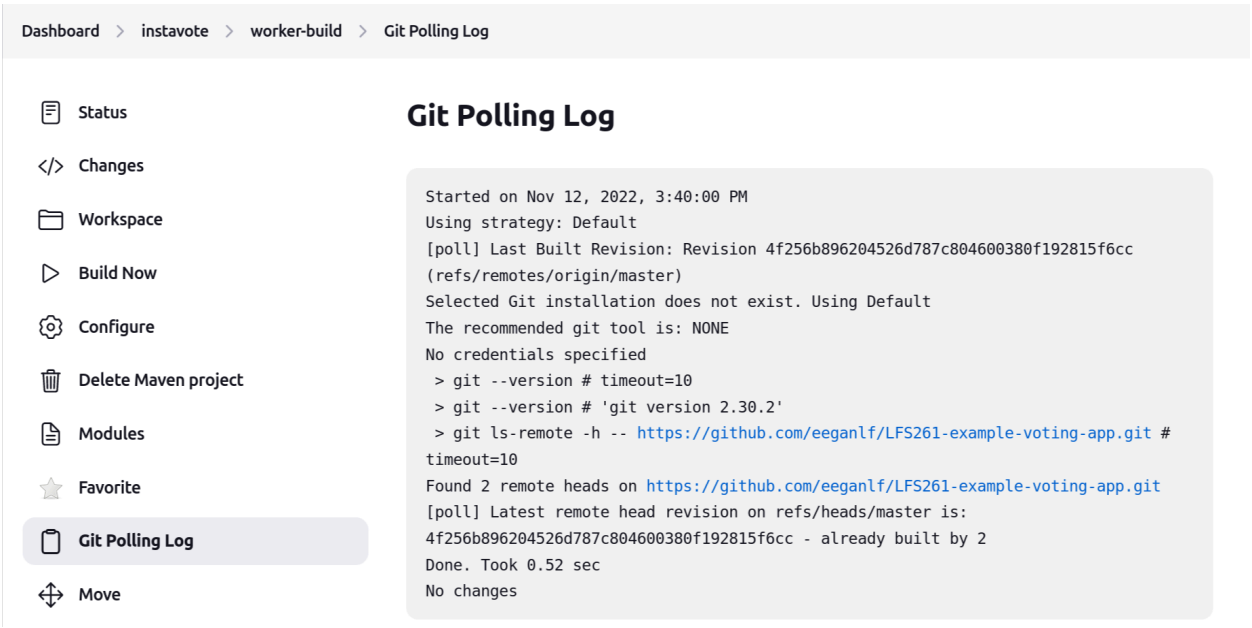
Configuring Build Triggers

You can use anything under **Build Triggers** to trigger automatic builds, but for now you are going to use **Poll SCM**.

Go to the `worker-build` job configuration page > **Triggers** and choose **Poll SCMs**. To periodically poll the Git repository, type or paste the following in the **Poll SCM** schedule:

```
H/2 * * * *
```

Once you have made changes, save the job, and go to your job page, where you will find the **Git polling log** in the left panel. Check your polling logs by clicking **Git Polling log**. It may take a minute to run.

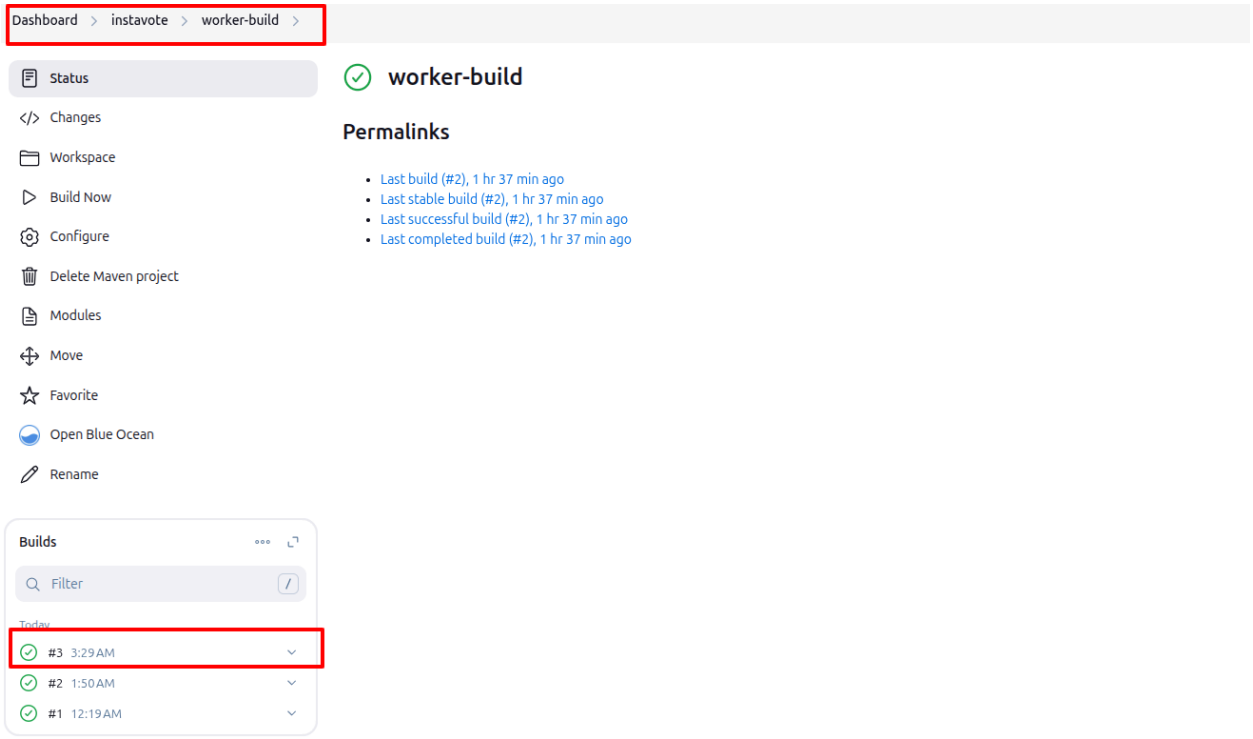


Now you will trigger builds remotely. Navigate back to **worker-build > Configuration** and scroll to the **Triggers** section. Select **Trigger builds remotely**. You can type any characters randomly into the token box, but be sure to remember what you put in as you will use it as the token to trigger a build.

A trigger URL is displayed just below where you defined the token. Your custom trigger URL will be similar to the following with your Jenkins instance IP address and port number. TOKEN_NAME should be replaced with the text you entered into the **Authentication Token** text box:

```
http://IPADDRESS:8080/job/instavote/job/worker-build/build?token=TOKEN_NAME
```

Save the configuration. Enter your URL in the browser and press **Enter**; you *may* see a page asking you to proceed, but you may see no indication that anything has occurred. You can verify that the URL ran the build by checking **Build History** at the bottom of the left pane in your Maven **`worker-build`** project page and seeing that one more build has occurred:



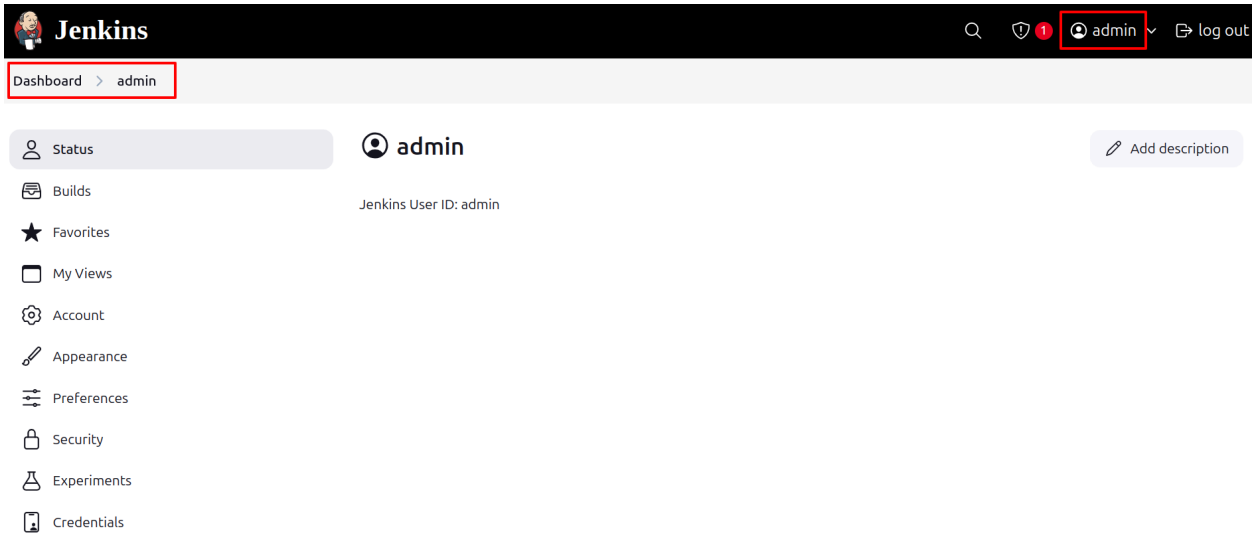
Click **Proceed** if the UI appeared and, since you are already authenticated, you should see the job launched automatically. Verify this from the project page.

You can't use this URL by itself outside of a browser session you are already logged into Jenkins with. You will need an API token tied to a Jenkins account for authentication and authorization.

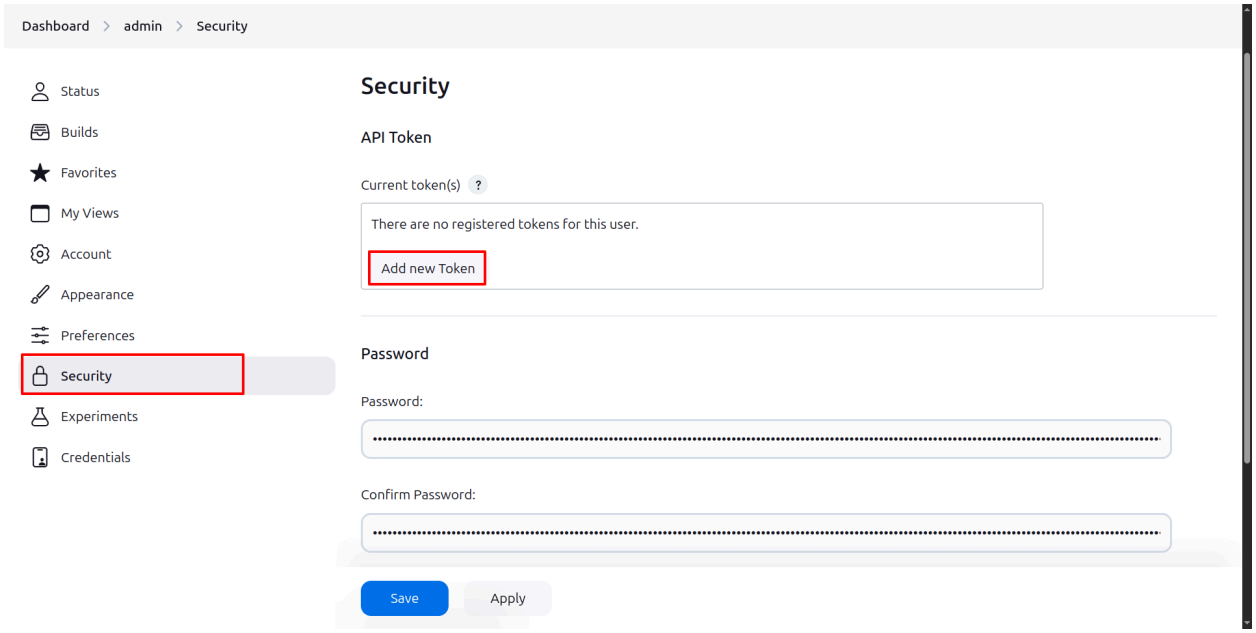
You can trigger the build using a command line interface or programmatically from external code

by providing an API token associated with a Jenkins user.

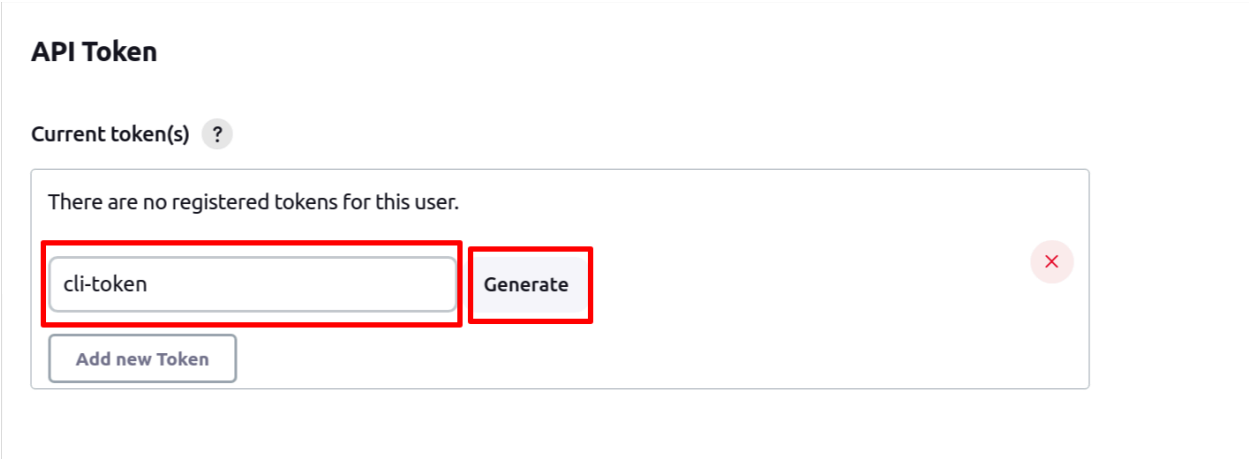
To create an API token, browse to **Jenkins -> UserAccount** as shown in the following image:

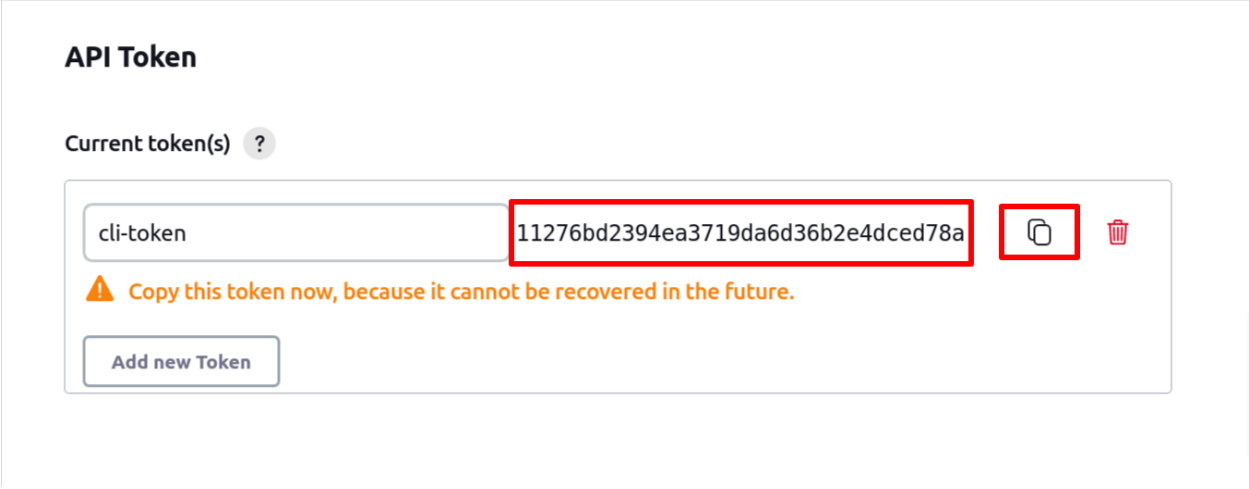


Browse to **Security** and **Add new Token**:



Name the token “cli-token” and click **Generate**:





Copy the API token and put together a remote trigger URL similar to the following where **`API_TOKEN`** is the token you just created and **`BUILD_TOKEN`** is the token you entered in the **Triggers** step:

```
http://admin:API_TOKEN@IPADDRESS:8080/job/instavote/job/worker-build/build?token=BUILD_TOKEN
```

Test trigger the build using a **`curl`** command or equivalent:

```
curl
http://admin:API_TOKEN@IPADDRESS:8080/job/instavote/job/worker-build/build?token=BUILD_TOKEN
```

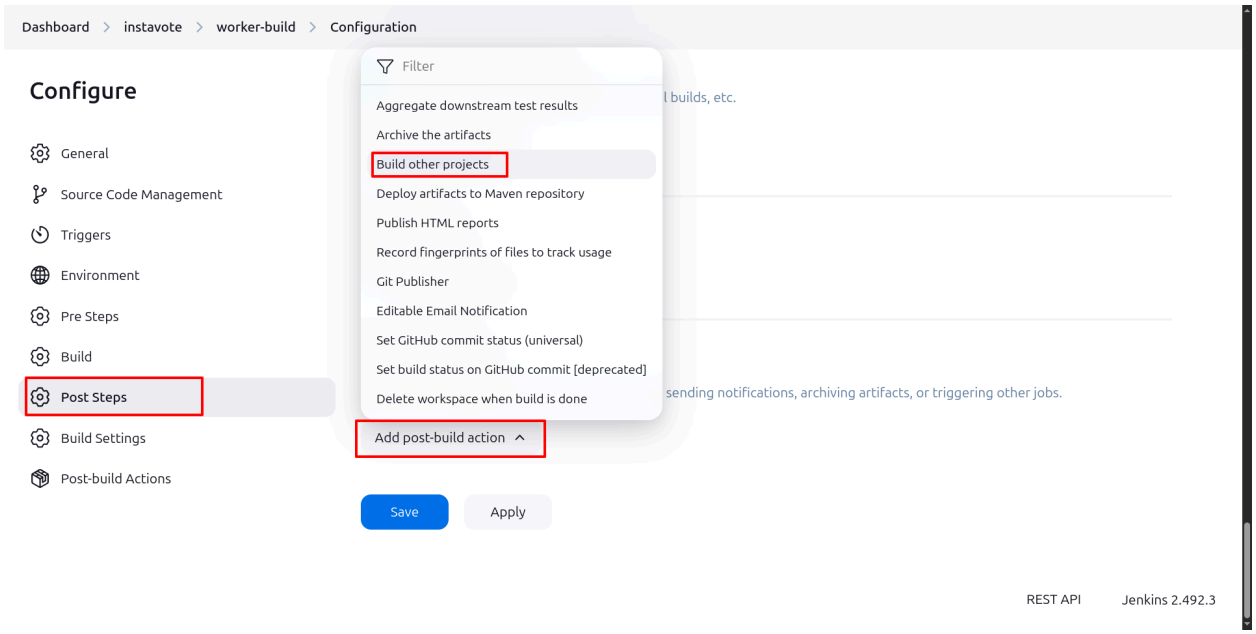
The above instructions demonstrate how to trigger builds remotely.

Creating a Job Pipeline

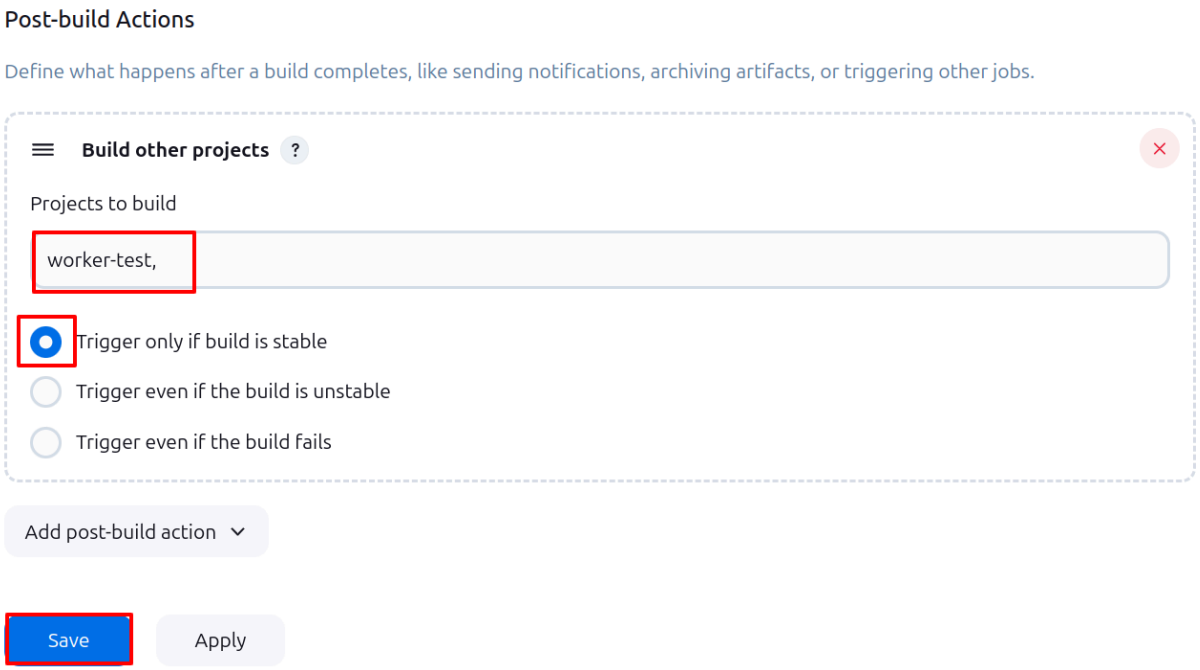
Now you will link jobs by defining upstreams and downstreams. You will also create a pipeline view using a plugin.

Follow these steps to set up upstream and downstream jobs.

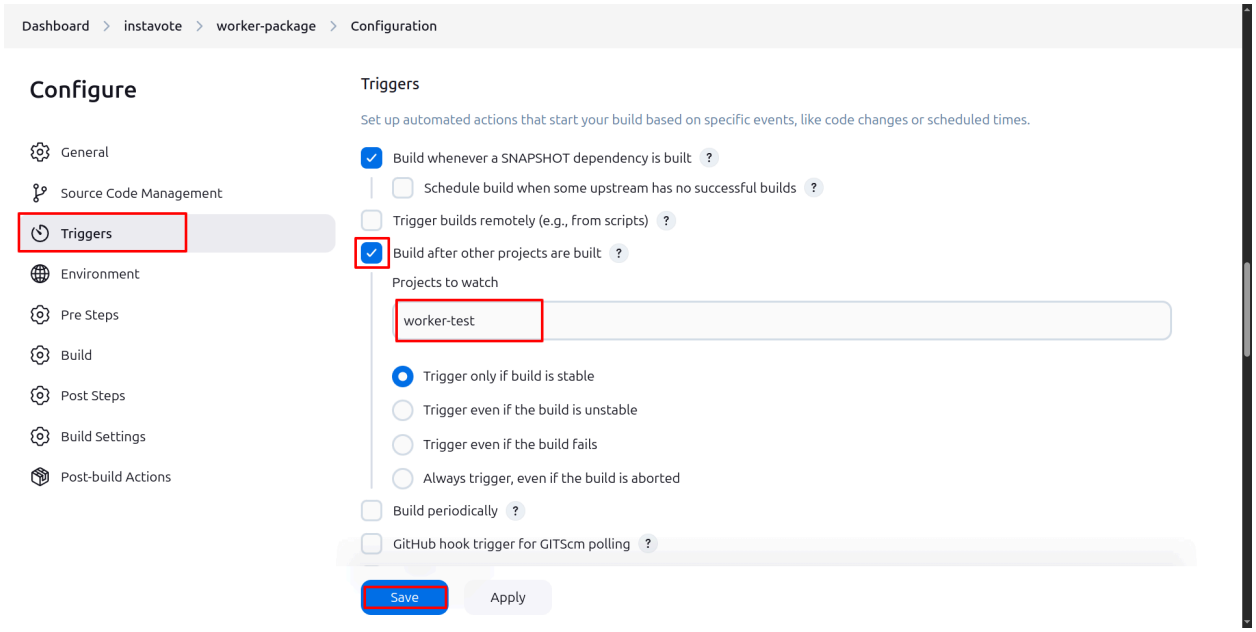
From the `worker-build` job configuration page, scroll all the way to **Post-build Actions,** click **Add post-build action** and select **Build other projects**.



This is where you will define the downstream job. Provide `worker-test` as the project to build and save.



Now you are going to set up the upstream for `worker-package`. Go to the `worker-package` configuration page. From **Triggers**, check the box for **Build after other projects are built**. Put `worker-test` in the **Build after other projects are built** input box.



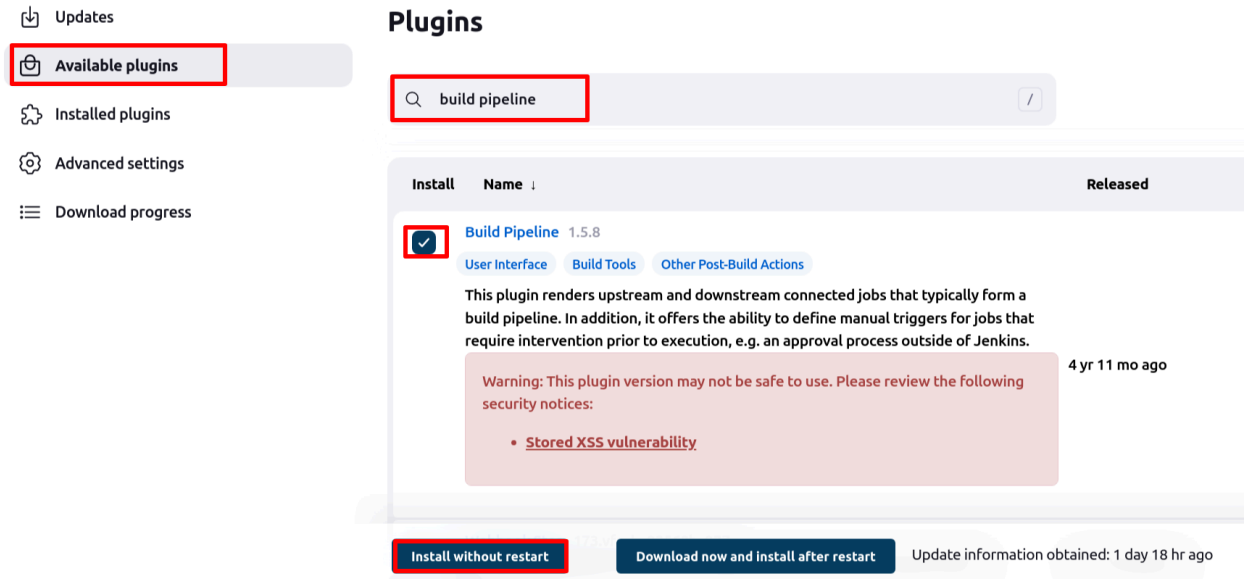
This defines the upstream for **`worker-package`**.

Once upstreams and downstreams are defined, run **`worker-build`** and it will automatically run **`worker-test`** and **`worker-package`**.

Set Up the Pipeline View

Next, you are going to set up a pipeline view for this build job.

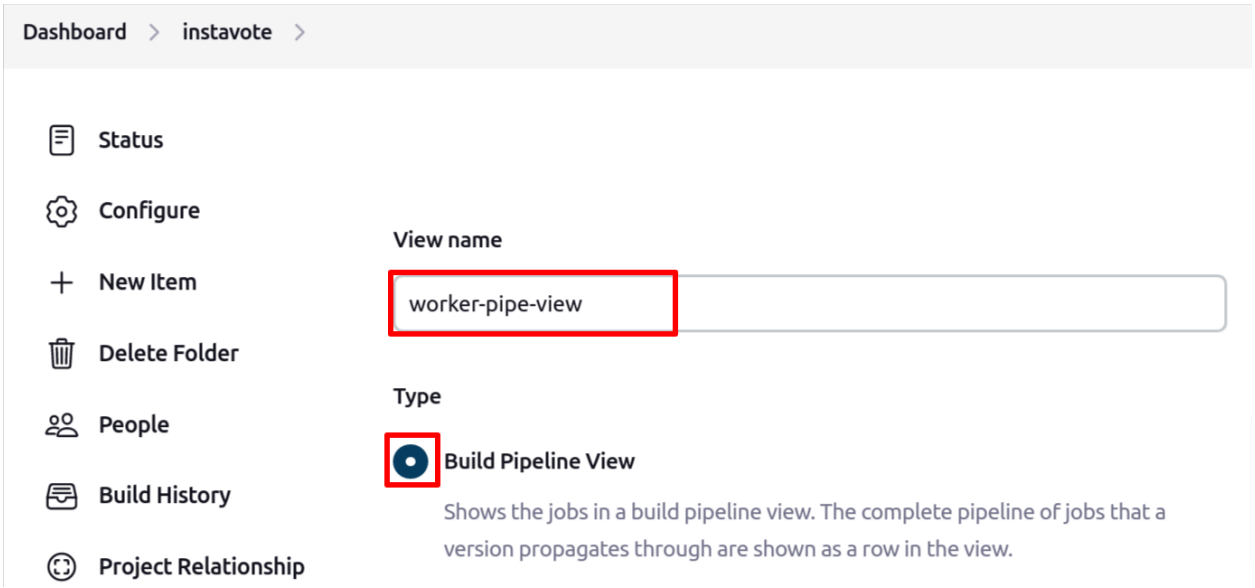
Begin by installing the Build Pipeline plugin from the **Manage Jenkins > Manage Plugins** page. Type *build pipeline* in the search box, select the **Build Pipeline** plugin and click **Install without restart**.



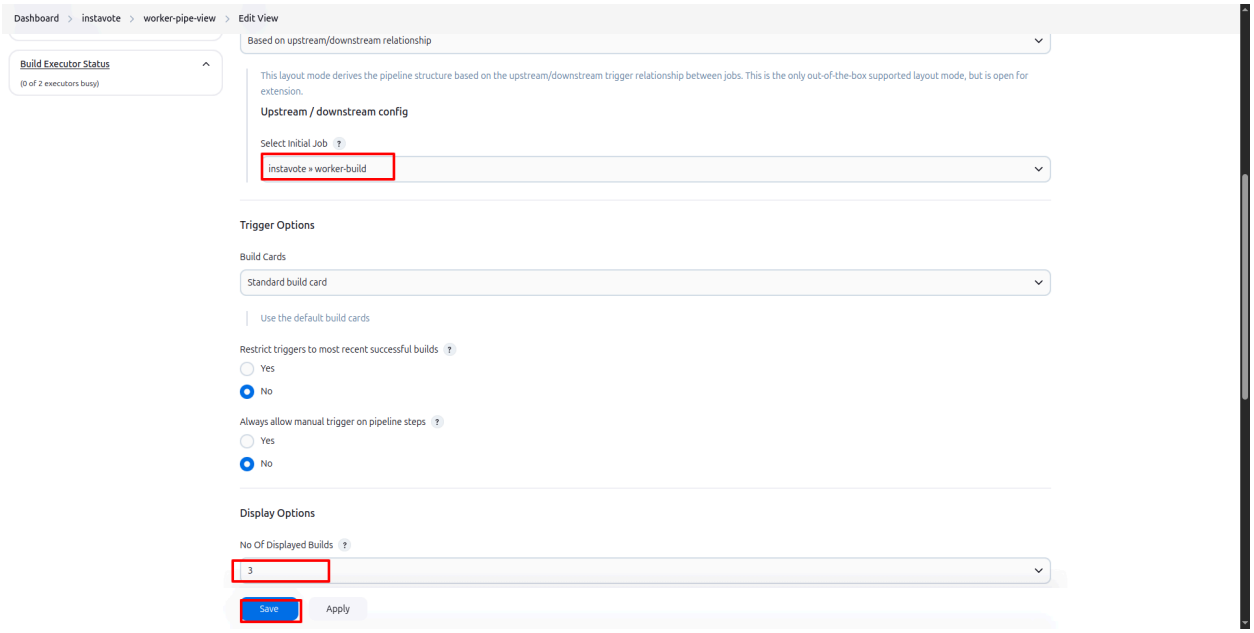
***NOTE**: You may see a vulnerability warning while installing the Build Pipeline plugin. It's not recommended that you install this plugin in a production environment. You are using this plugin only during this lab to aid your understanding of creating pipelines. Starting with the next chapter, you will use the Jenkinsfile, which does not need this plugin to provide you with a pipeline view. Jenkinsfiles are used in a real production environment.*

Click on the `instavote` folder and you will now notice a **+** sign under the title. Click on it:

Select **Build Pipeline View** and provide a name for it, e.g. “worker-pipe-view”, then click **Create**:



From the configuration page, select the first job in the pipeline, **`worker-build`**, and select the number of displayed builds as 5, then save it.

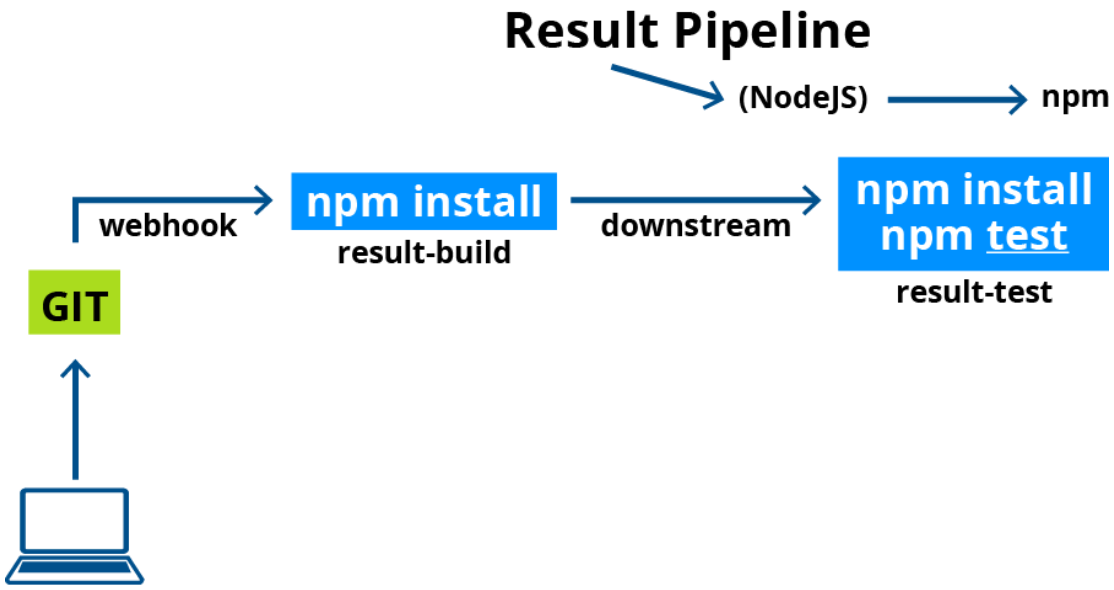


Once you complete, you will see the pipeline of your job. Green is successful, red is failed, blue is to do, yellow is in progress.

You have just created a pipeline for a Java project.

Exercise: Create a Pipeline for the Node.js Application

Now that you are familiar with creating CI pipelines, try creating one for the Node.js `result` application with `npm`.



Steps:

- Install **NodeJS** plugin for Jenkins.
- Configure **Global Tools** with a NodeJS installation with version 22.4.0.
- Create two jobs `result-build` and `result-test`, this time as freestyle projects.
- Define the Git repository you have forked in the **Source Code Management** section.
- Define the build trigger as **PollSCM** with an interval of 2 mins.
- In the build environment, choose to add NodeJS configurations with the version you have selected in **Global Tools**.
- Select the **Execute Shell** option from build and provide the commands to build the Node application from the `result` subdirectory. For example:

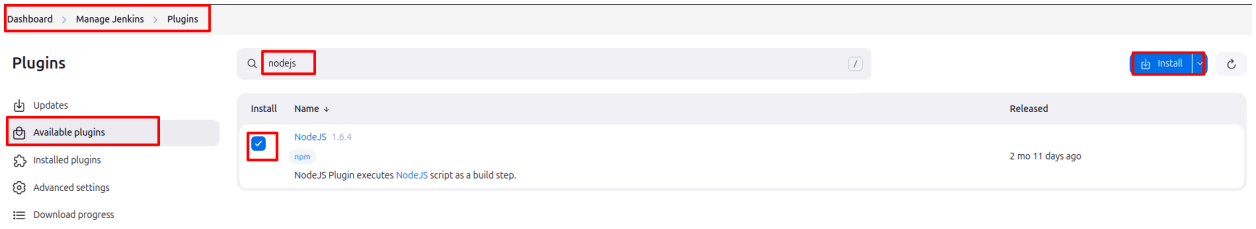
```
cd result

npm install

npm test
```

Summary

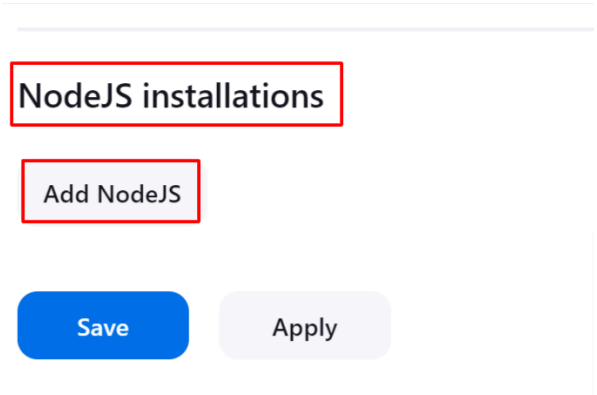
In this lab, we set up Jenkins using Docker Compose. We forked the **`instavote`** app so that we could work with our version of the app. We then used Jenkins to set up an integration pipeline for our **`instavote`** app on GitHub. Finally, we added a visual representation of the build pipeline.

Lab 4S. Creating A Pipeline for the NodeJS Result Application (Solution)

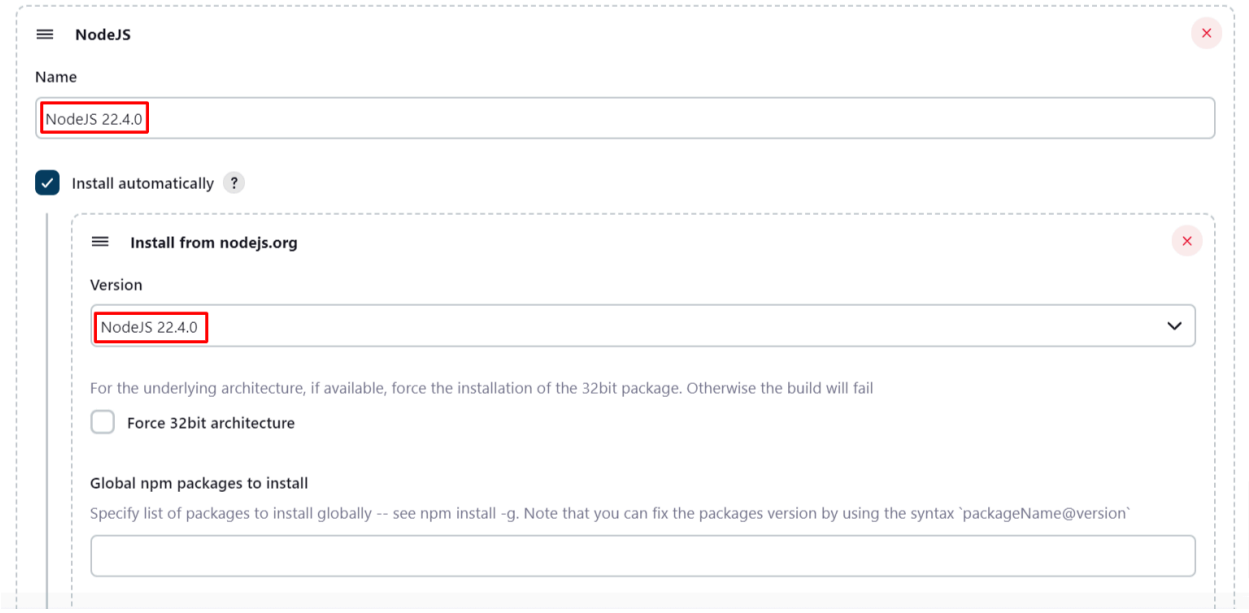
Install the **NodeJS** plugin for Jenkins.



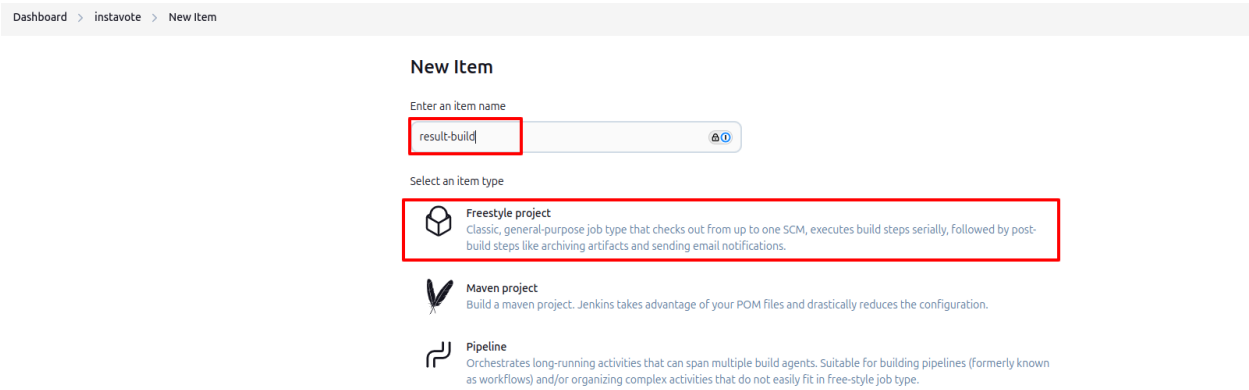
From **Jenkins > Manage Jenkins > Tools > NodeJS Installations**, add a NodeJS installation with version 22.4.0.



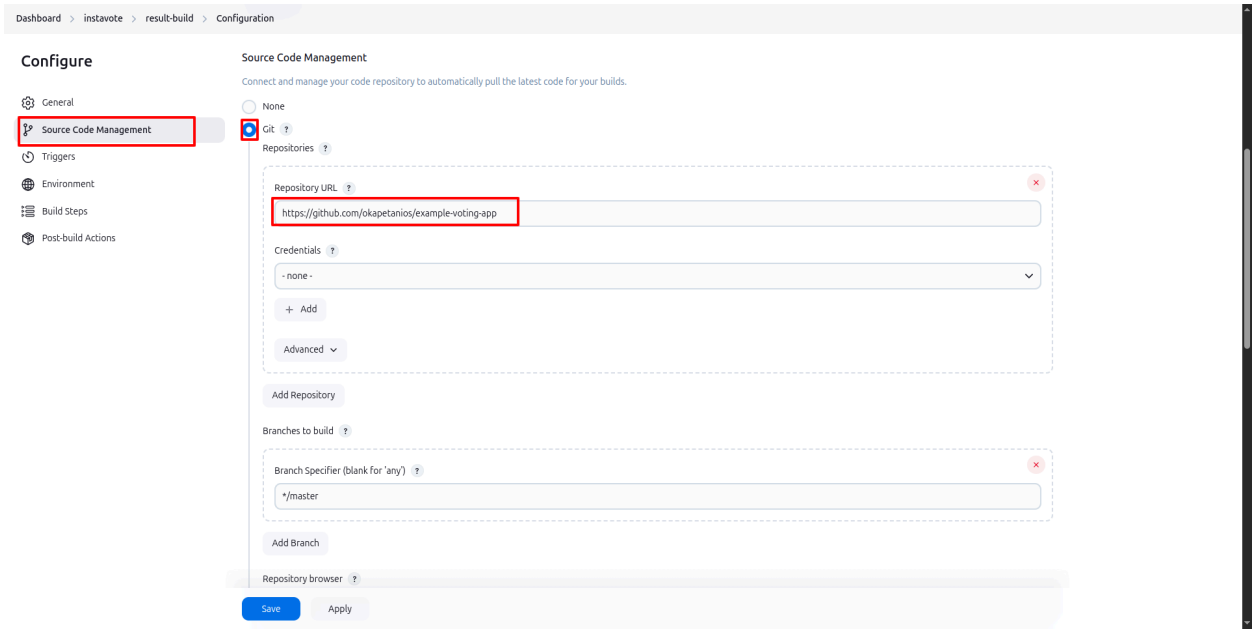
Name the installation exactly **NodeJS 22.4.0** as the name will be referred to later in the pipeline.



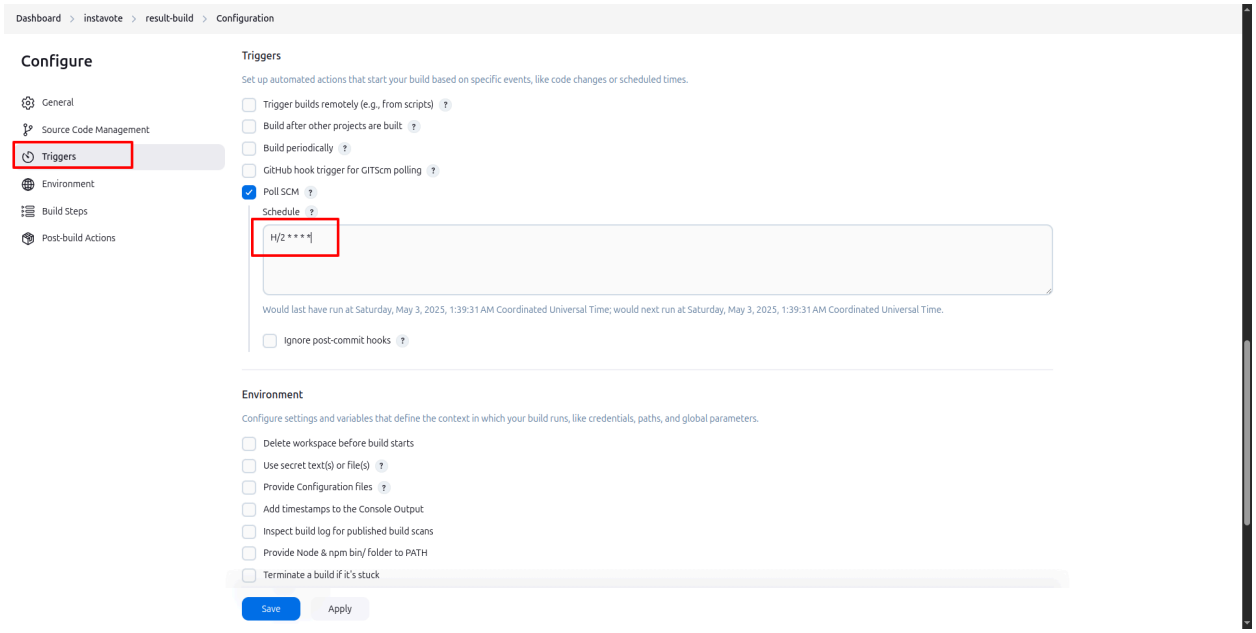
Create a new job inside the `instavote` folder called **`result-build`**, this time as a freestyle project.



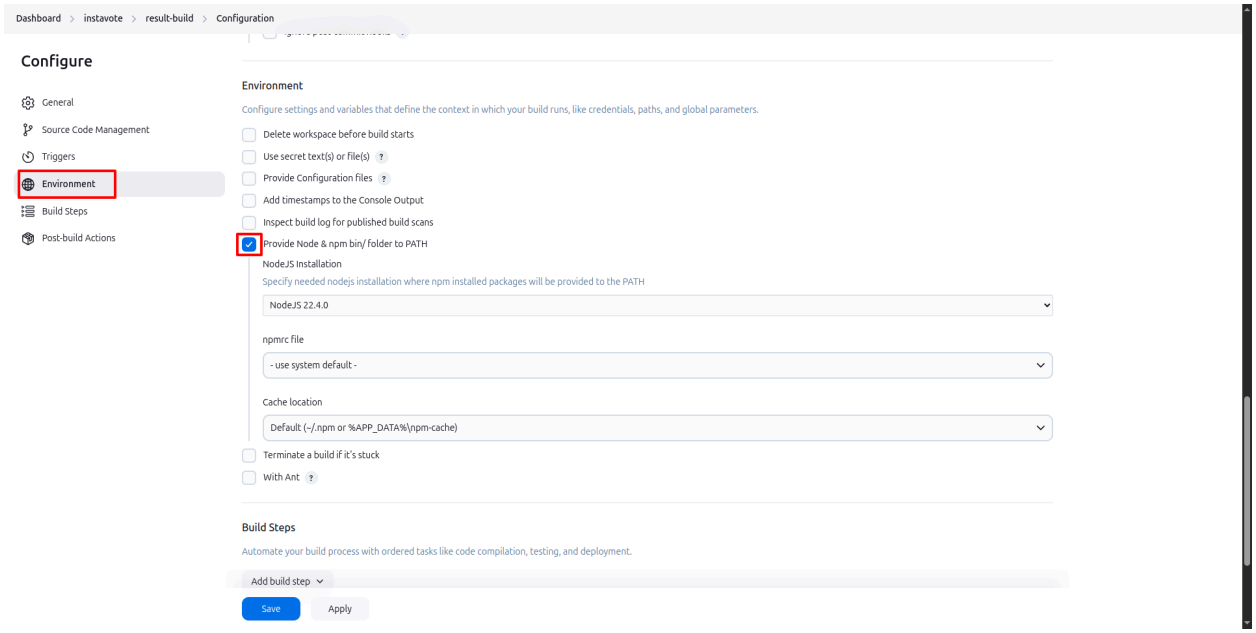
Paste in the `example-voting-app` Git repository that you forked in the **Source Code Management** section.



Select **Poll SCM** with an interval of 2 mins by pasting `H/2 * * * *` into the **`Schedule`** input box.

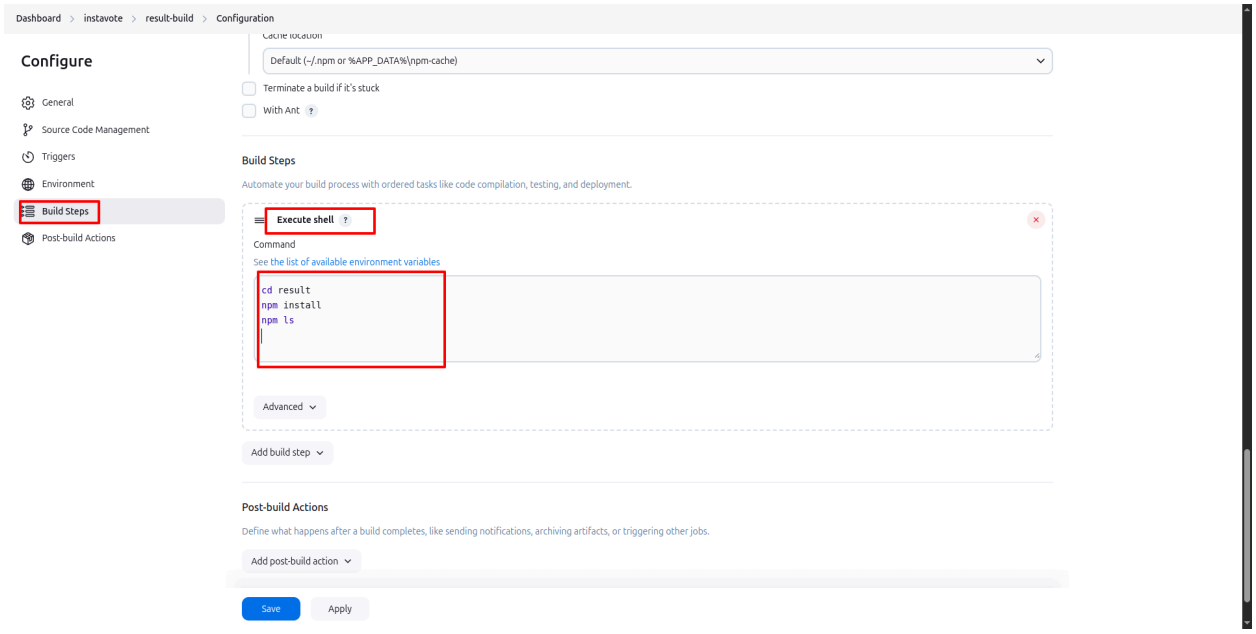


In the **Environment** choose to provide NodeJS configurations with the version you have selected in the **Global Tool Configuration**.



Select the **Execute shell** option from **Build steps > Add build step** and paste or type the following into the box:

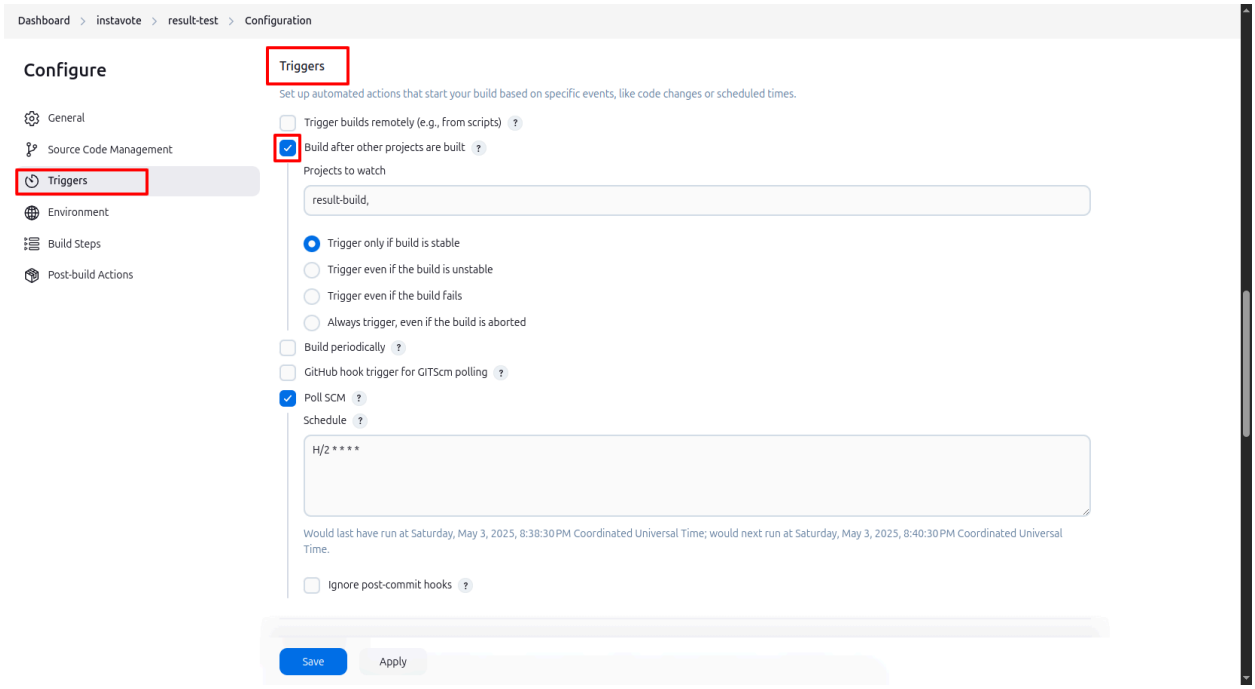
```
cd result

npm install

npm ls
```



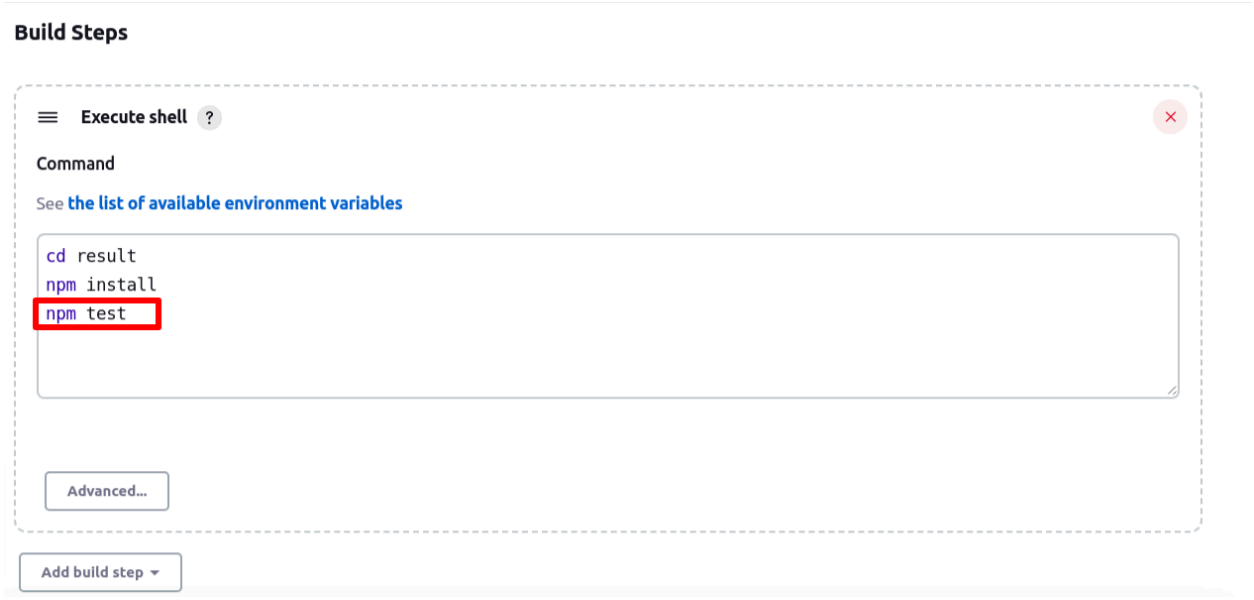
Save the project and build it.

Create another project with the name **`result-test`**, this time copying from **`result-build`**.

Change the build trigger to run after **`result-build`** is run.



Update the command to run **`npm test`** instead of **`npm ls`**.



Create a new pipeline view, this time by choosing **`result-build`** as the first job to run.

After **`result-build`** runs, wait a few moments and refresh the page; you should see both jobs turn green in the pipeline as follows:

This completes the CI pipeline for the **`result`** app created with NodeJS.

Lab 4.1. Setting Up Continuous Integration with Jenkins (Additional Topics)

Optional: Integrating GitHub with Jenkins

***WARNING**: This will only work if your Jenkins server is available publicly and can be accessed from GitHub. If you are running Jenkins on your local machine (e.g. laptop) with a private IP space, this will **not** work unless you use some method to expose your local machine to the public internet. This is beyond the scope of this course, but you can look into ngrok, boring proxy, or localtunnel as possible solutions. Be aware that this will have security implications.*

By the end of this exercise, you should be able to:

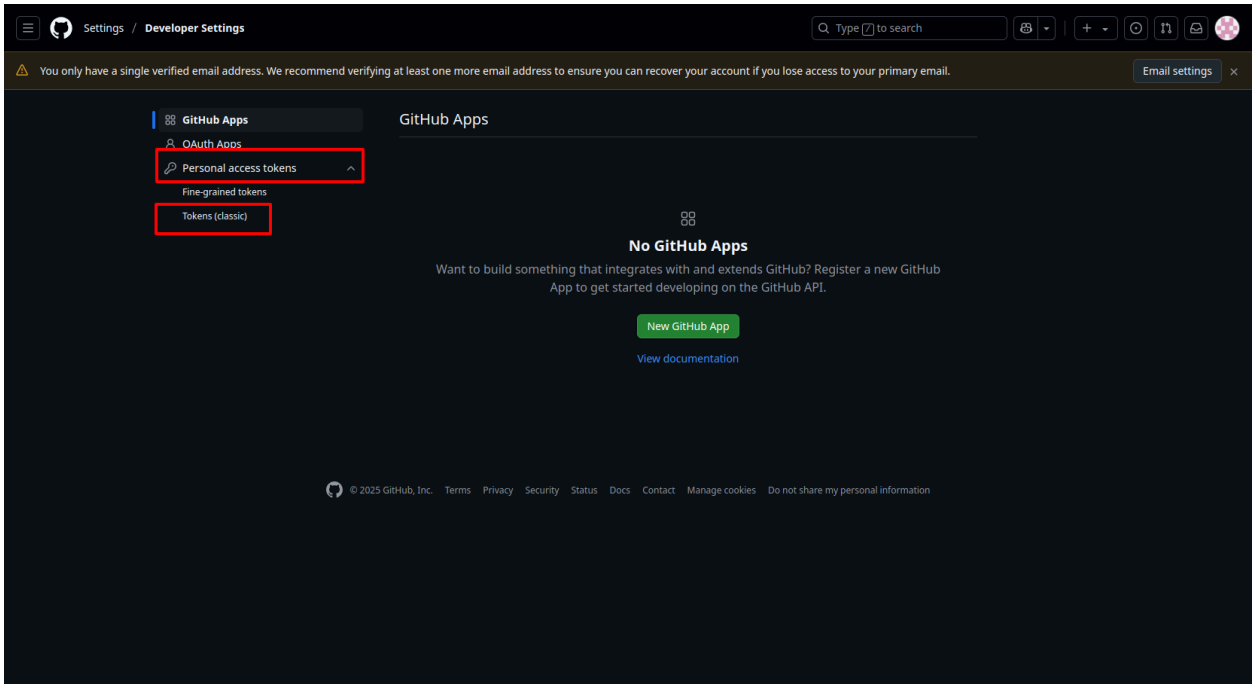
- Integrate GitHub with Jenkins
- Trigger builds automatically using GitHub webhooks

Setting Up Build Triggers Using GitHub Webhooks

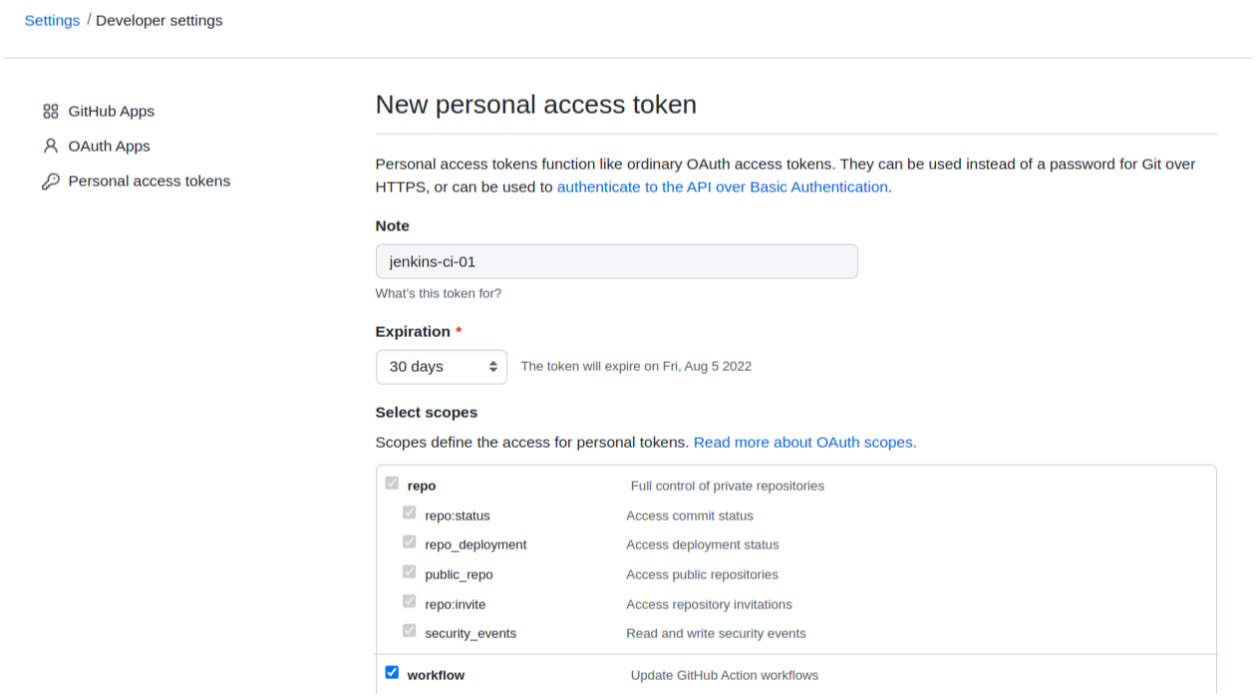
You can trigger your job when there is a commit change in the master branch on GitHub. Webhooks will trigger your job from the GitHub side and you can send the status back to GitHub, so you don't need polling from Jenkins.

Follow these steps to set up the Webhook.

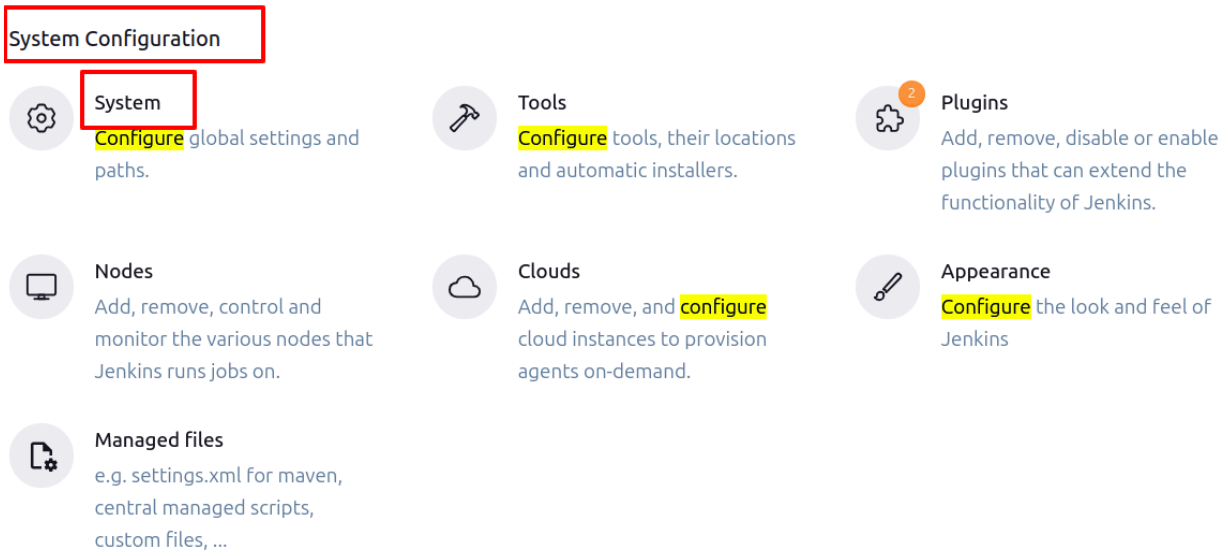
To set up a GitHub token, go to the user page and select ***Settings > Developer settings > Personal access tokens > Tokens (classic)***.



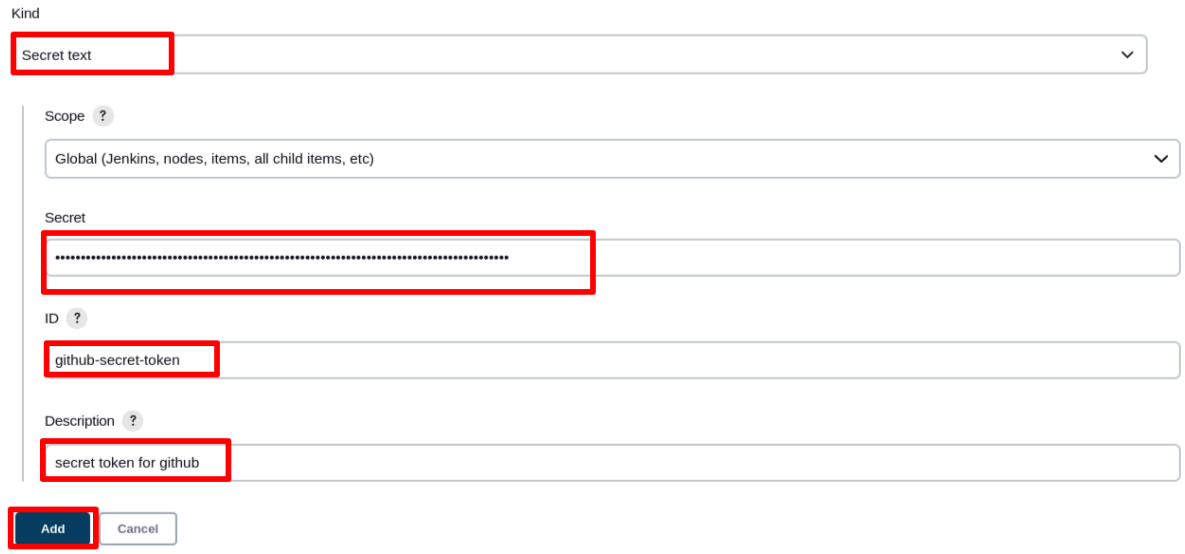
In the **Personal access token** page select **Generate new token > Generate new token (classic)**, add a note, check *all* boxes, and generate the token. Once you generate your token, save it somewhere immediately because you can't view it again.



Now go to **Jenkins page > Manage Jenkins > System Configuration > System**.

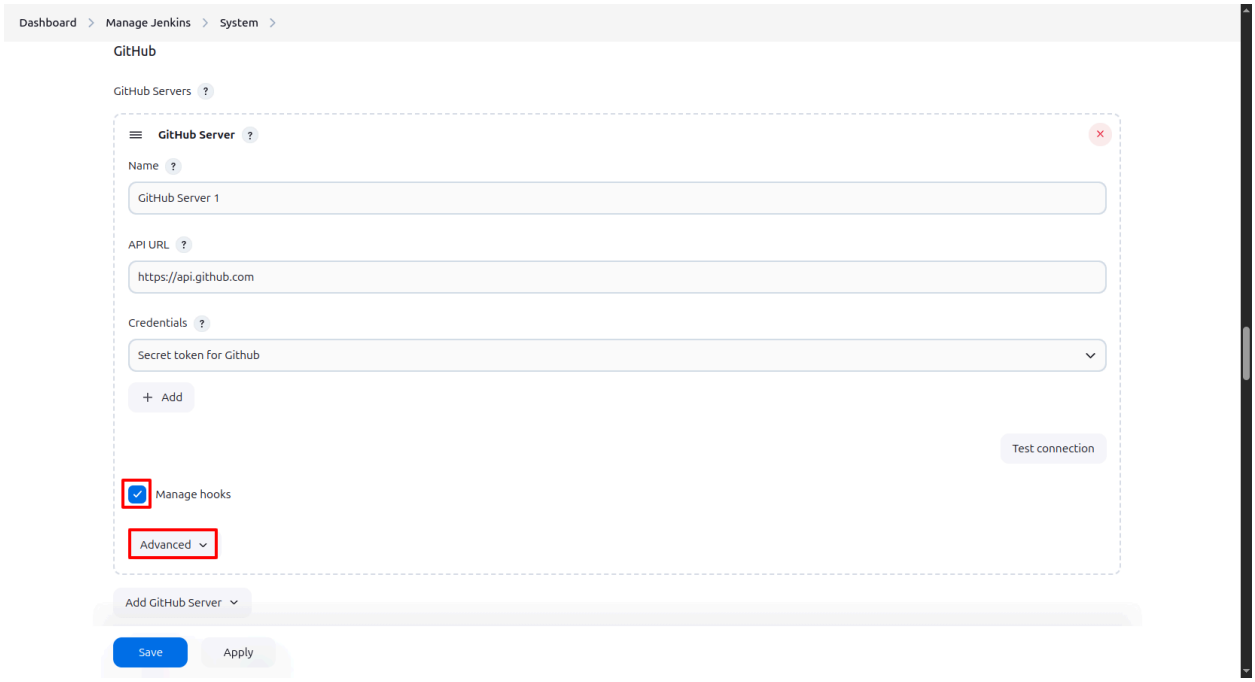


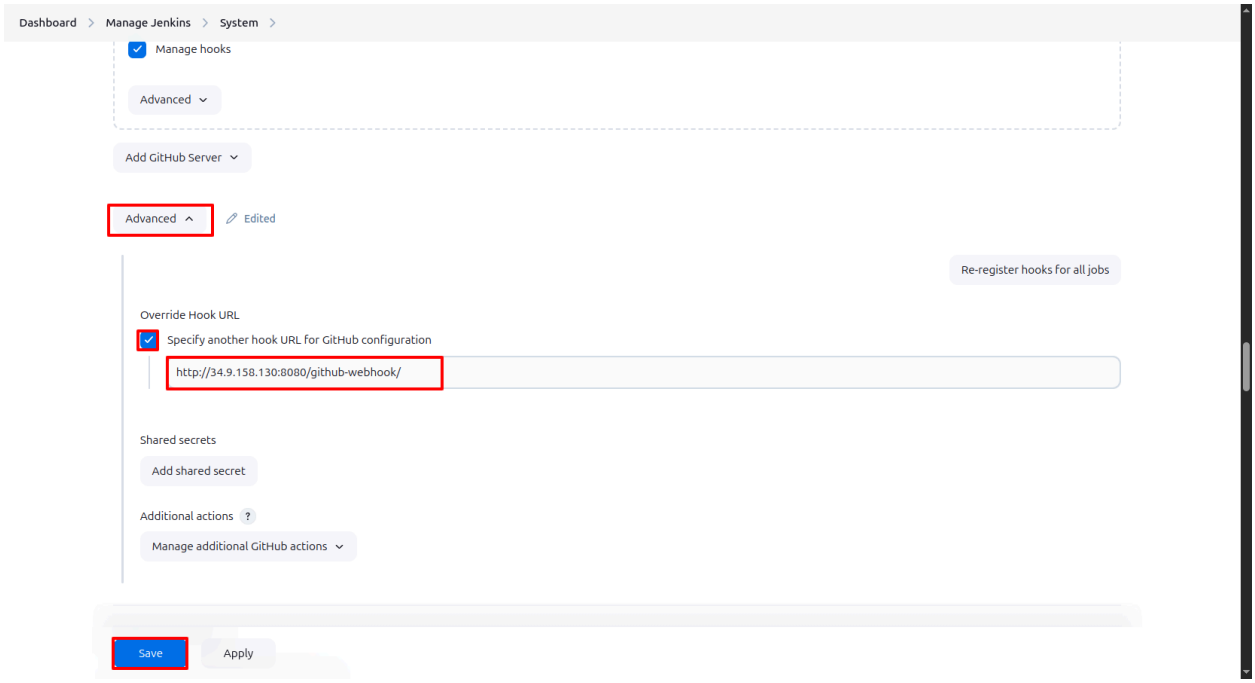
Scroll to **GitHub** and click **Add GitHub Server**. Provide any name for the server. This does not matter. Click **Add** under **Credentials** which brings up the following:



The secret is your GitHub access token that you generated. Provide an ID description. Save it.

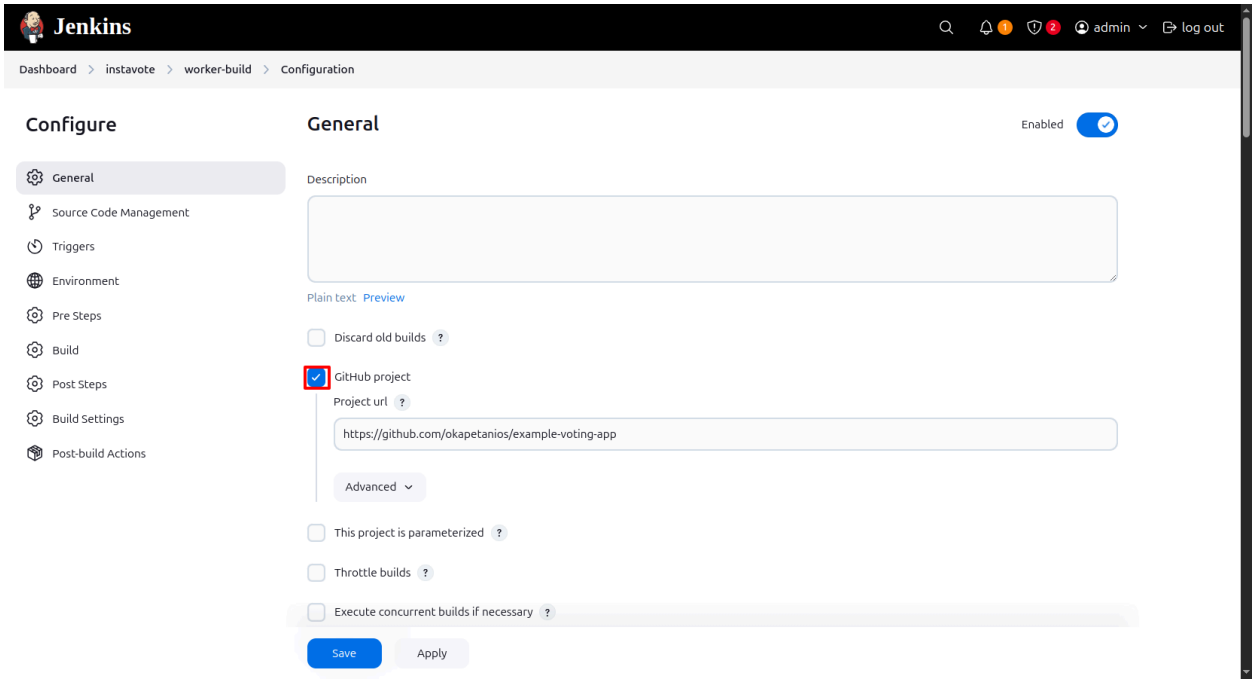
Choose “secret token for github” under credentials and check the **Manage hooks** box.





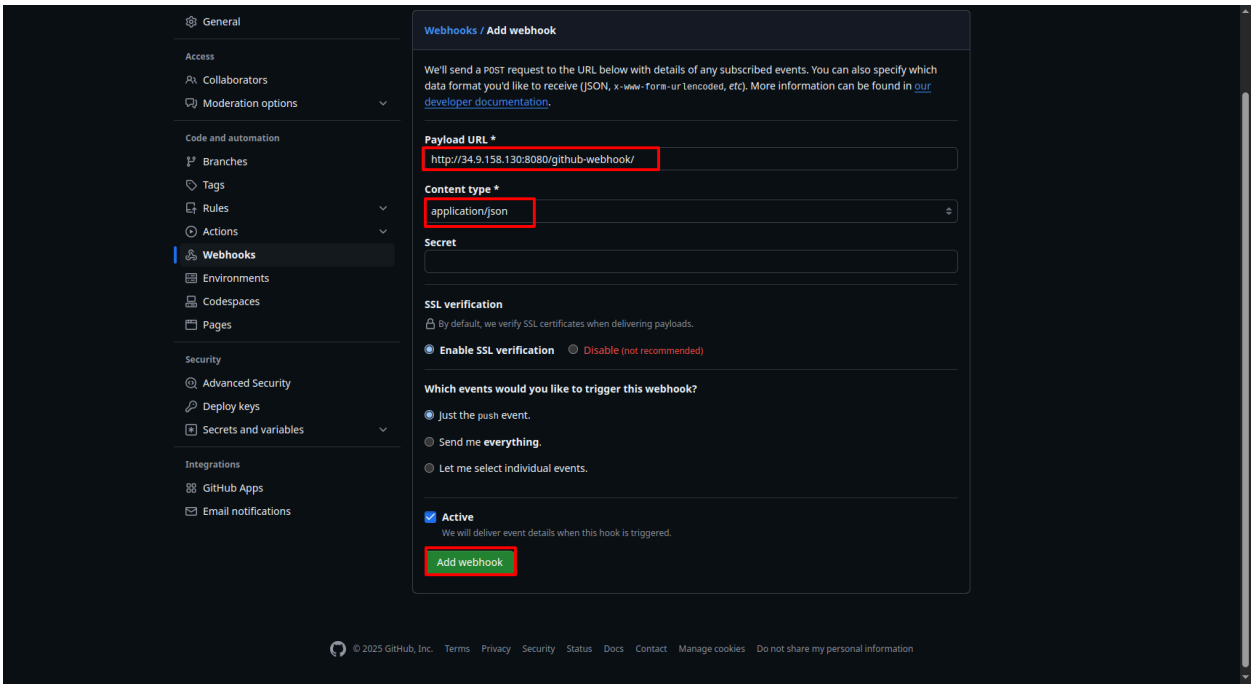
Copy the web hook address and save it for later. We will need to give this to GitHub in a few steps.

Go to your **`worker-build`** configuration page, choose “github project” and provide the **`example-voting-app`** repository URL.



Remove **Poll SCM** and choose **GitHub hook trigger** for Git SCM polling, save the changes.

Go to the GitHub repository and choose ***Settings > Webhooks***. Add “Payload URL” and “Content type” as “application/json”. Save it (refer to the example image given below).



Next, go to the Git repository, add some file in your repository and commit the changes.

Once you make the commit in your repository, it will automatically trigger your build. You can see it by using the build pipeline you created earlier.

This is how you integrate GitHub with Jenkins.

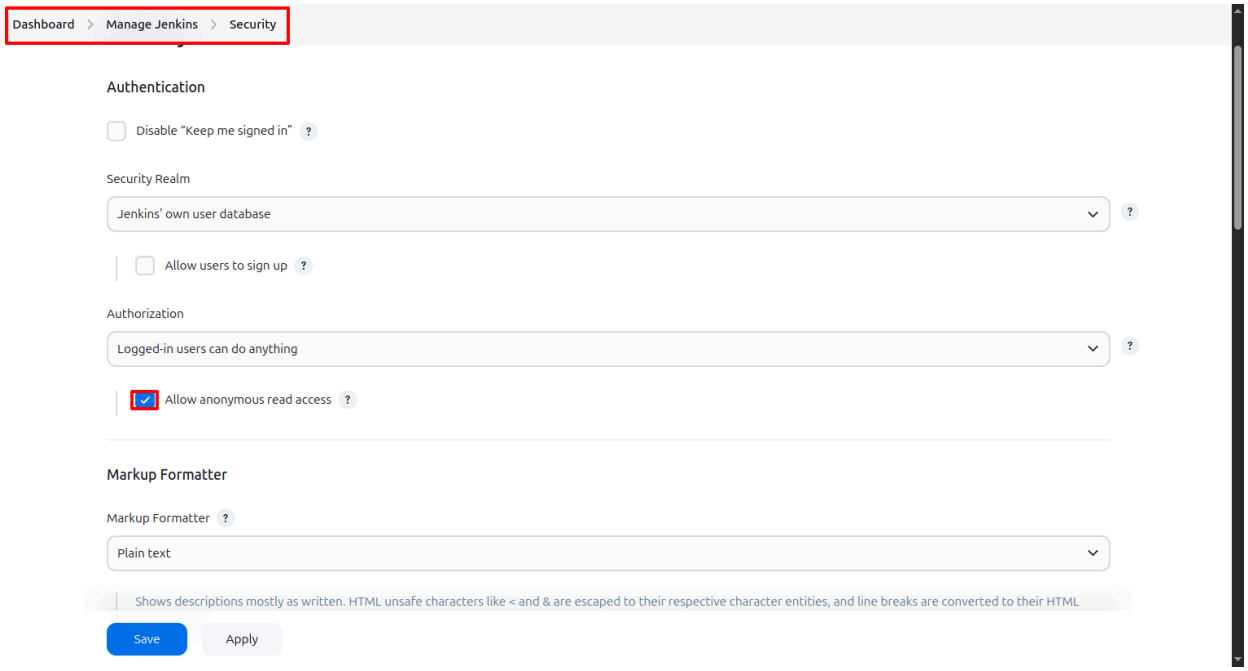
Optional: Adding Jenkins Status Badges to GitHub

***WARNING**: This only works if the Jenkins server is accessible from GitHub.*

By the end of this exercise, you should be able to:

- Set up a two-way communication between Jenkins and GitHub
- Send the status of the build from Jenkins to GitHub and display it as a badge

First, allow anonymous read access so GitHub can access the necessary information. **Dashboard > Manage Jenkins > Security > Authentication > Allow anonymous read access**:

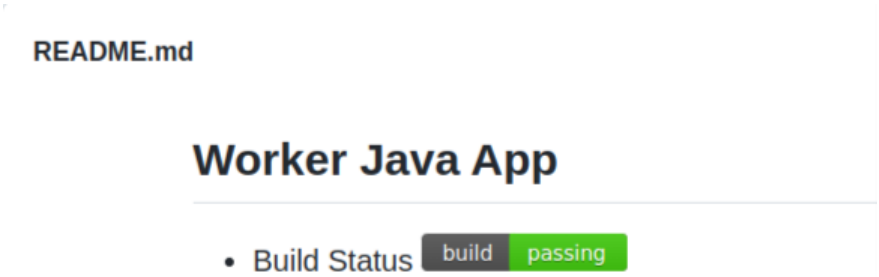


You need to install the **Embeddable Build Status** plugin from *Manage Jenkins* > *Plugins* > *Available plugins*. Once the installation is done, you can see **Embeddable build status** on every job page.

Follow the next steps to add the Jenkins status badge to GitHub.

Go to the `worker-build` job page, select **Embeddable Build Status** from the menu on the left. On the **Embeddable Build Status** page, scroll to **Links** and under **Markdown** copy the **unprotected** link. Paste it in your GitHub repository `README.md` file which you have created in the previous lab and commit the changes.

Once you commit the changes, you should see the build status being listed as passing on your `README.md` file.



Go to the **`worker-build`** configuration page. Under the **Build** section change the root file to **`pom.xml`** instead of **`worker/pom.xml`** and save the changes.

Build your **`worker-build`** job; it will fail your build. Now go to the GitHub repository page. There you can see the build's failed status on the **`README.md`**.

Correct the **`worker-build`** by switching **`pom.xml`** back to **`worker/pom.xml`**.

If you wish, you can add the embeddable build status unprotected markdown link of **`worker-test`** and **`worker-package`** to your GitHub repository **`README.md`** file as well.

This is how you add the Jenkins status badge to GitHub.

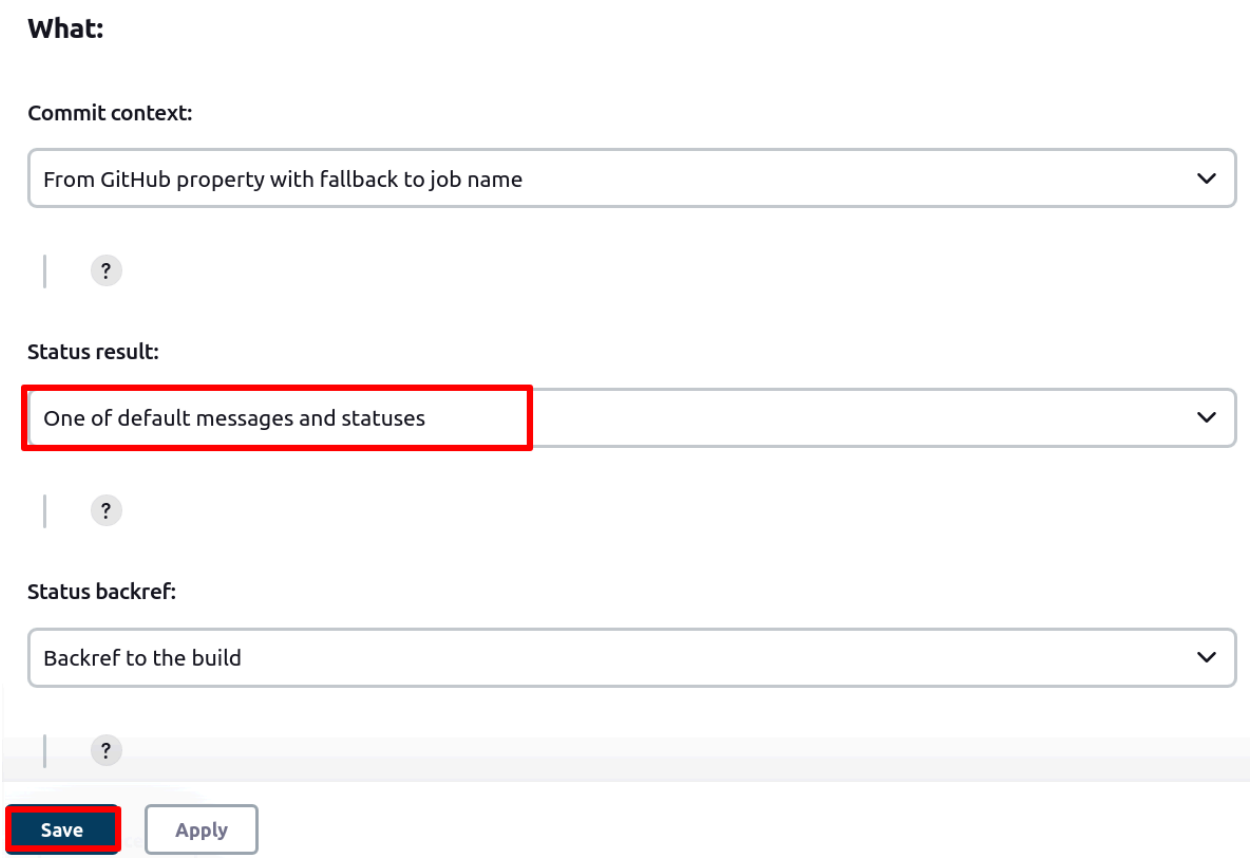
Optional: Configuring Job Status with Commit Messages

By the end of this exercise, you should be able to:

- Add build and test job statuses to GitHub commit messages

Follow these steps to configure the job status.

Go to your **`worker-build`** job configuration page, under **Post-build Actions**, **Add post-build action** and choose "Set GitHub commit status (universal)" and set the **What > Status Result** to *One of default messages and statuses*. Save the changes.



Go to the `worker-test` configuration page and paste the GitHub project URL into the **Source Code Management** section. Add the post-build action "Set GitHub commit status (universal)" in the same way that you did for the `worker-build` job. Be sure **What > Status result** is set to *One of default messages and statuses*.

Now go to your `worker-test` job page. There, select the **Embeddable Build Status**. In the **Embeddable status** page, copy the markdown unprotected link under **Links** and paste it on your GitHub repository `README.md` file. Add `subject=Unittest` to your `worker-test` link as follows:

The unprotected markdown link will look similar to the following:

```
[![Build
Status](http://IPADDRESS:8080/buildStatus/icon?job=instavote%2Fworker-test)](h
ttp://IPADDRESS:8080/job/instavote/job/worker-test/)
```

You need to add `subject=UnitTest` like so:

```
[![Build
Status](http://IPADDRESS:8080/buildStatus/icon?job=instavote%2Fworker-
test&subject=UnitTest)](http://IPADDRESS:8080/job/instavote/job/worker
```

```
-test/)
```

Once you commit the changes, it will automatically build the triggers. You can see the builds in the pipeline view and the status will be updated on GitHub.

If you check your commit messages, it shows them as check-marked. You can see all the current build statuses with build number on the git commit message. If you click **Details** in the commit message, it will take you to the Jenkins page.

This is how you configure the job status and **`git commit`** messages.

Lab 5. Enforcing Workflows, Pipeline as Code

By the end of this lab exercise, you should be able to:

- Define branch protection rules on GitHub
- Enforce code reviews via pull requests
- Write a pipeline as code
- Learn the syntax to write declarative Jenkins pipelines
- Create Jenkinsfiles for Java applications
- Launch multi-branch pipelines upon commits to a remote repository

Enforcing Workflow with Branch Policies

Resources:

- Web: Guide to Trunk Based Development
- Video: Trunk Based Development Explained

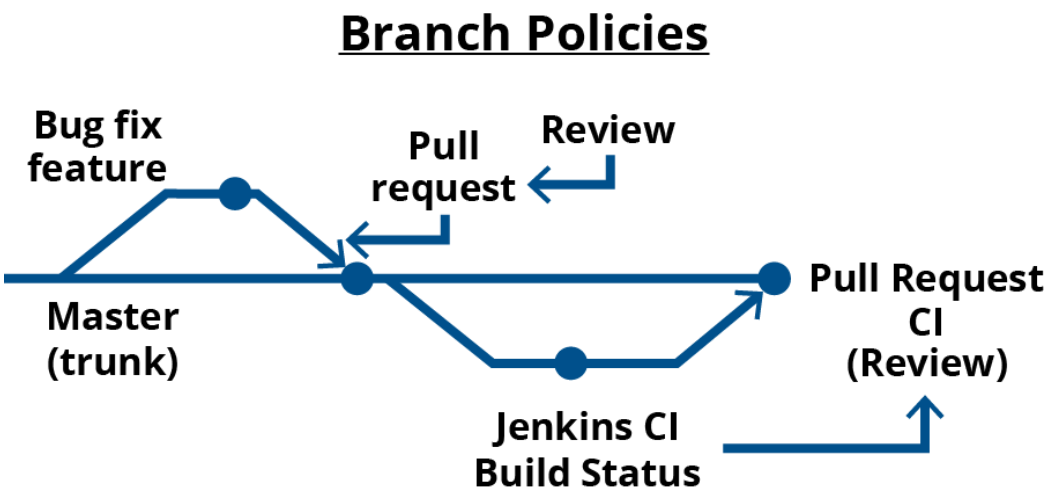
Let's create branch policies based on the trunk-based development workflow. With trunk-based development:

- The master branch is the trunk/main line of code, which is locked (no direct check-ins to master are allowed).
- Every bug fix gets its own branch.
- Every feature gets its own branch too.
- Feature branches are typically short-lived.
- Merges to master require pull requests.
- Further policies could be added to enforce code review, as well as integrate with Jenkins CI to run per branch pipeline.

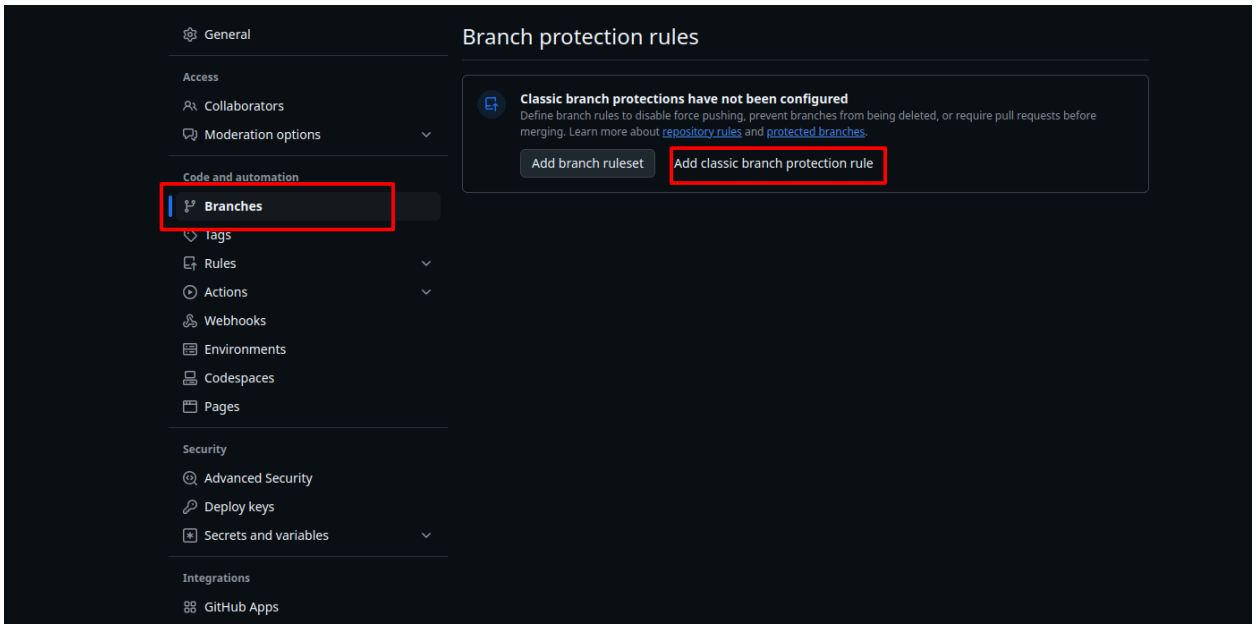
Make sure you have cloned your own fork of the `example-voting-app` repository locally before you proceed. Make sure you are currently inside the `example-voting-app` directory.

NOTE: If you do not have a collaborator, create another account on GitHub, add that account as a collaborator on the `example-voting-app` repository, and add it as a reviewer or skip to the Writing Pipeline as Code section.

This is how the process looks:



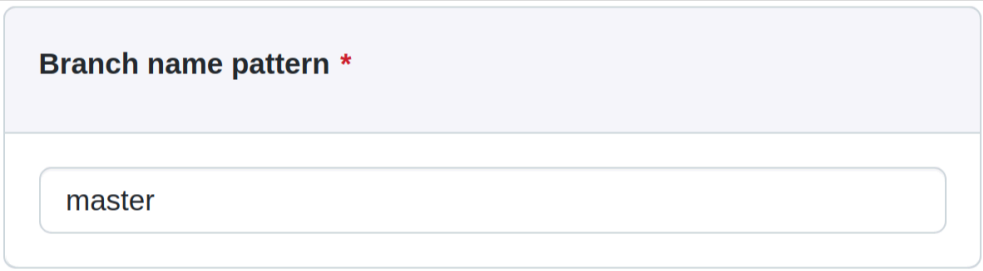
To define the branch policies, go to **Settings** for your `example-voting-app` repository on GitHub and select the **Branches** option.



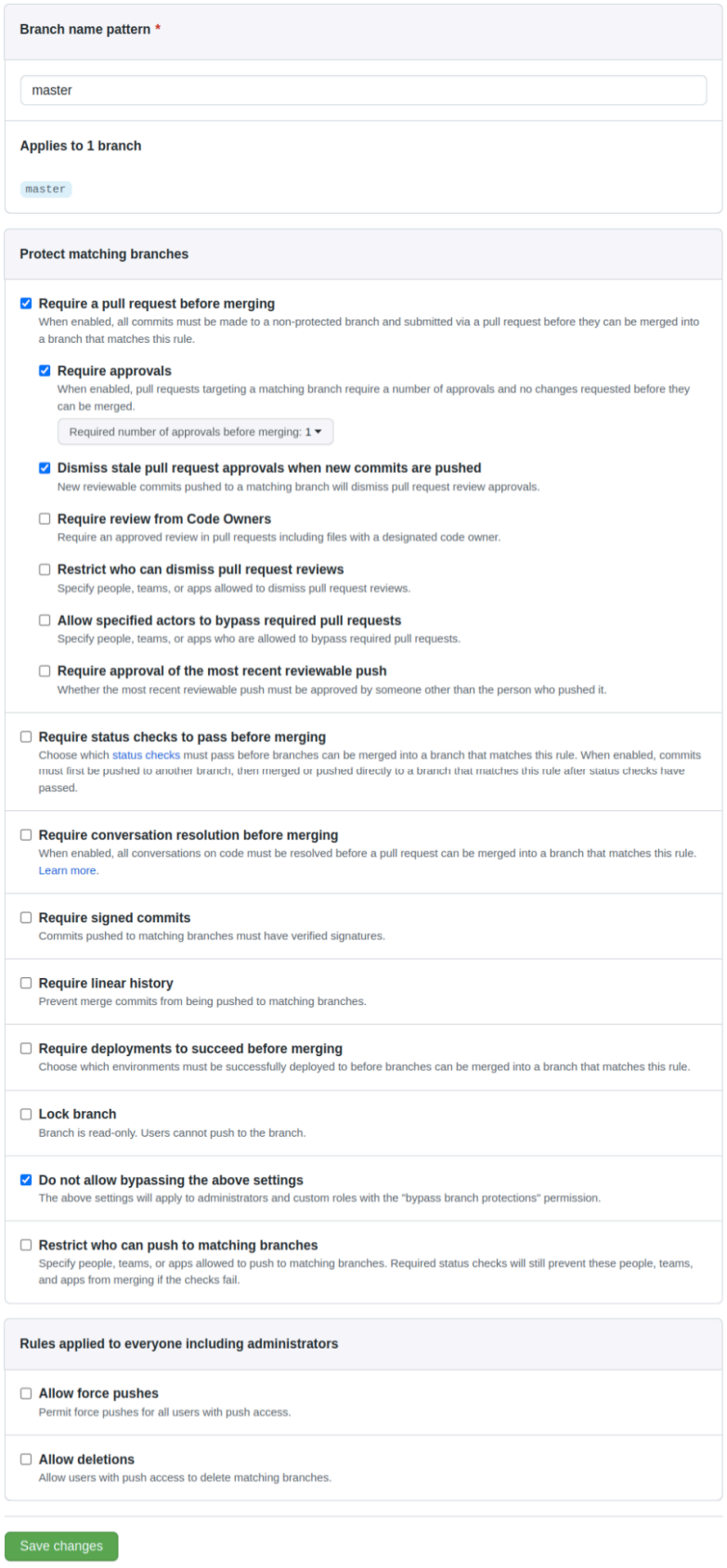
From the **Branch Protection Rules** section, click on the **Add branch protection rule** button. Add the following set of rules:

- Require pull request reviews before merging
- Dismiss stale pull request approvals when new commits are pushed
- Require status checks to pass before merging
- Do not allow bypassing the above settings

The following screenshots depict the branch protection rules:



Make the name the same as the branch, in this case **master**, that you want to add rules to.



Testing Your New Branch Protection Rules

To test the branch protection rules, from the local repository, make some changes to any file, e.g. `README.md`. Try adding it to Git and commit those changes:

```
git diff
```

```
git commit -am "test"
```

```
git push origin master
```

When you try to push the changes to a remote, it throws an error *"master protected branch hook declined"*. That's because you can't directly push to master anymore.

You can undo the changes by resetting the commit:

```
git log
```

```
git reset --hard HEAD~1
```

Once you do a hard reset, it will roll back the changes you have made to the commit history and also to the local workspace.

Code Reviews with Pull Requests

Next, you will learn how to make changes in the master branch by using code reviews and pull requests. Update the existing `README.md` file for the project and incorporate those changes to the trunk i.e. master branch.

Create a branch **`readme`** using the following command:

```
git checkout -b readme
```

Running this command will create the **`readme`** branch, and then switch to it. Update the `README.md` file by adding a description of the application.

For example,

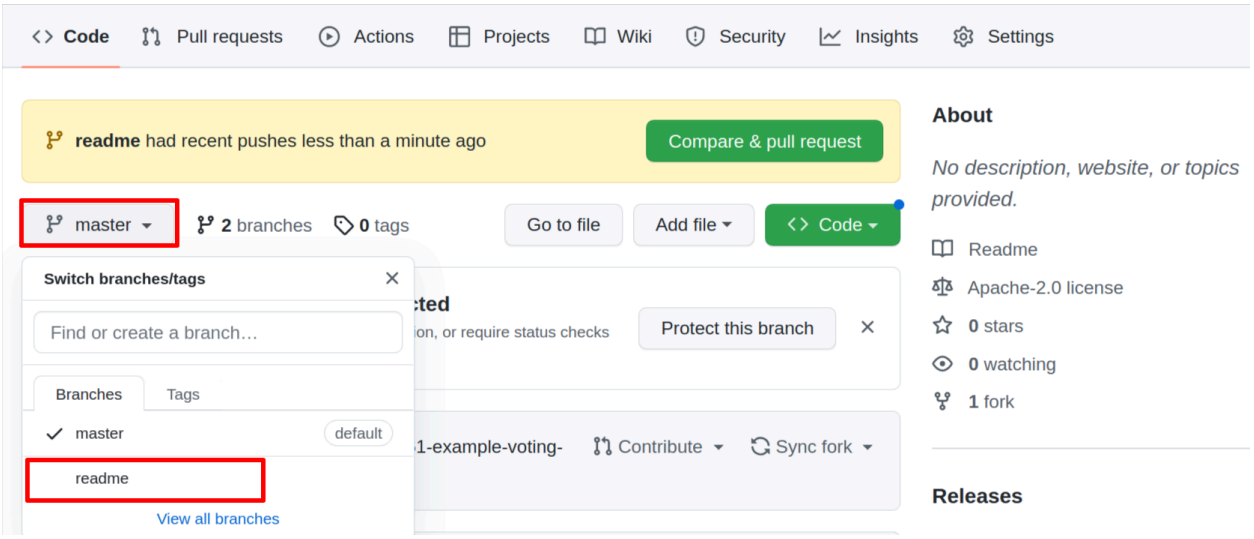
```
filename: README.md

Example Voting App
==========

This is a sample voting app.
```

Save and commit the changes you have made:

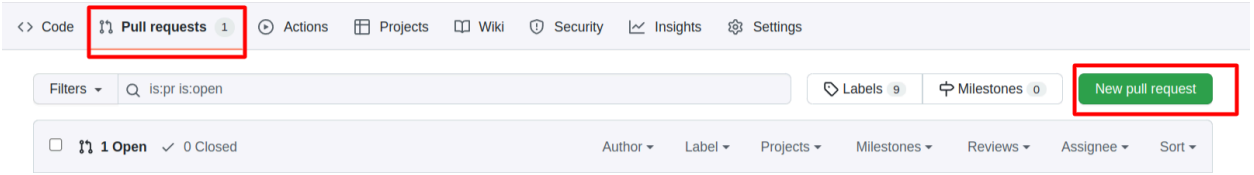
```
git status

git commit -am "added application info"

git push origin readme
```

This pushes the changes to the **`readme`** branch of the repo on GitHub.

Go to the GitHub repository and switch to the branch **`readme`**. You can do this by clicking the dropdown menu that has **master** currently selected:

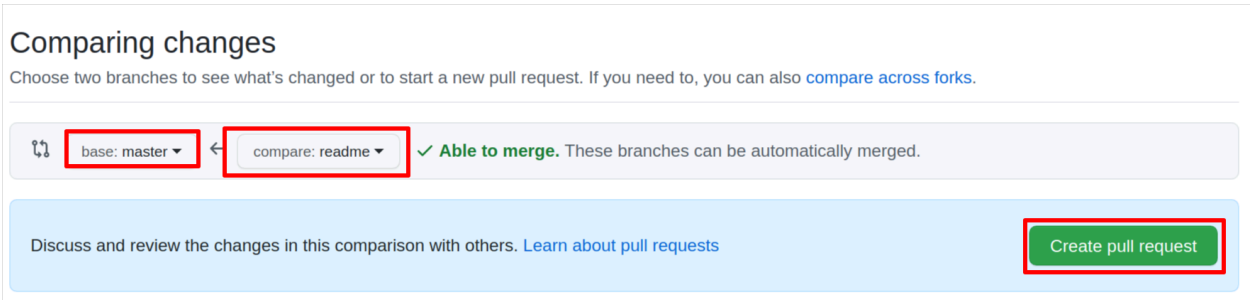


Select the **Pull requests** tab next to the **Code** tab across the top of the repository:

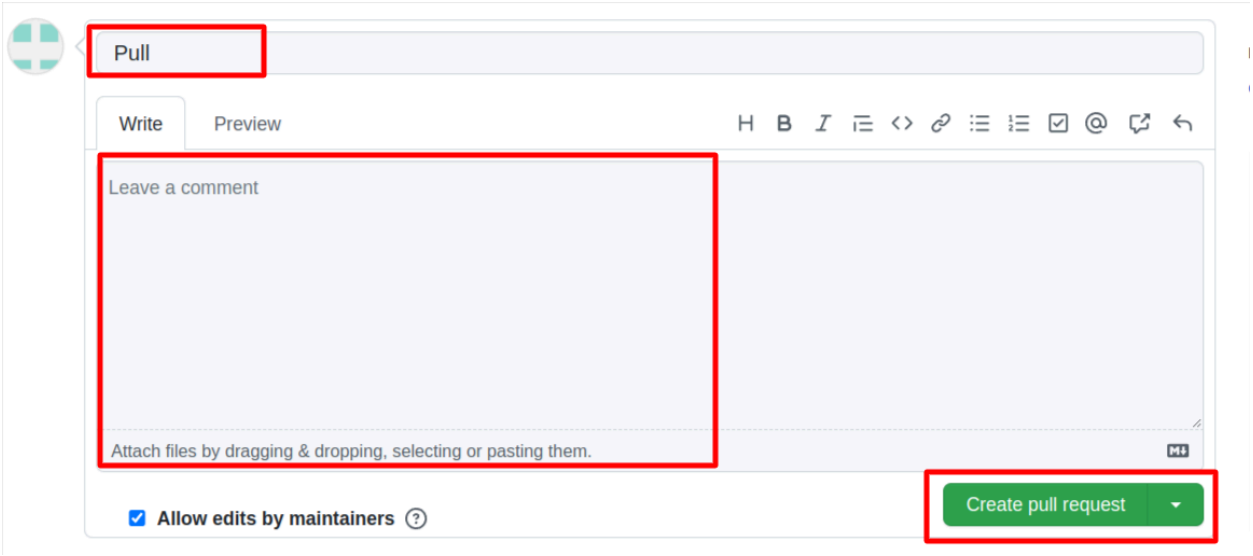


You should see **New pull request** to the right. The pull request is to allow you to merge the changes from the feature branch on GitHub to the master branch on GitHub.

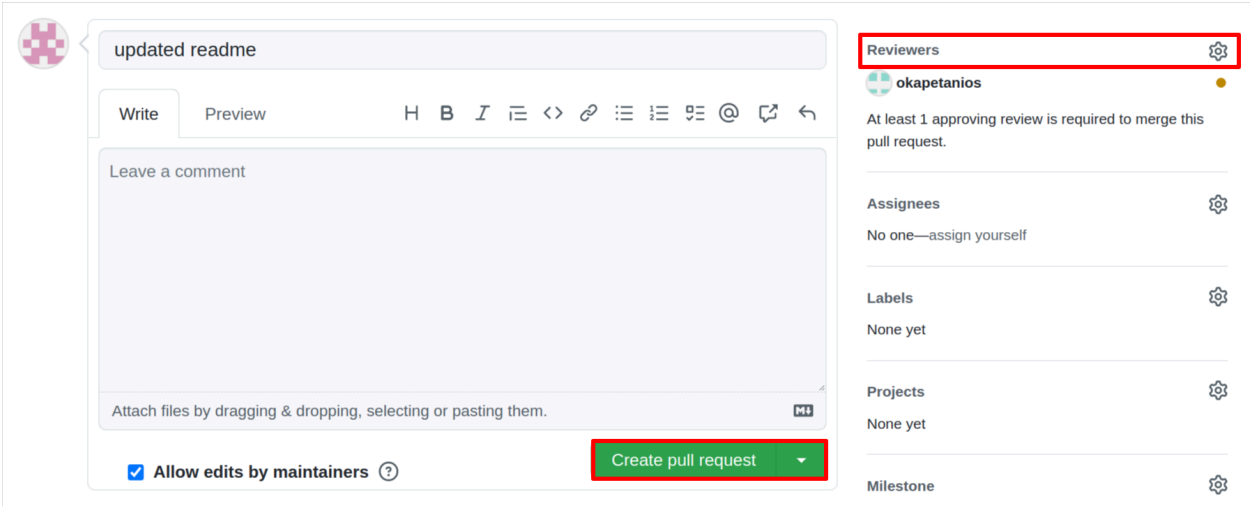
Select **New pull request** and choose your repository for the **base repository** and choose **master** for the **base**. Select your repository from the **head repository** dropdown and select the **`readme`** branch in the **Compare** dropdown. Click **Create pull request**.



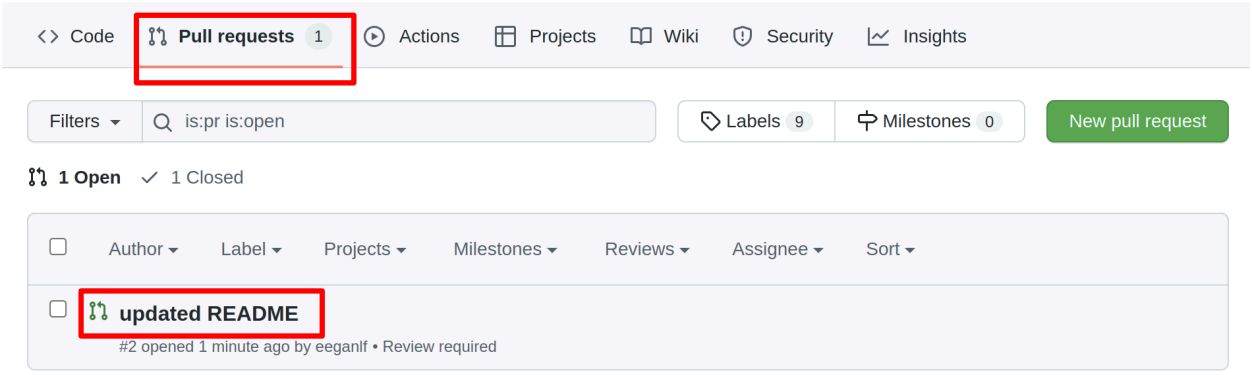
Enter the title and leave a comment if you'd like, then click **Create pull request**:



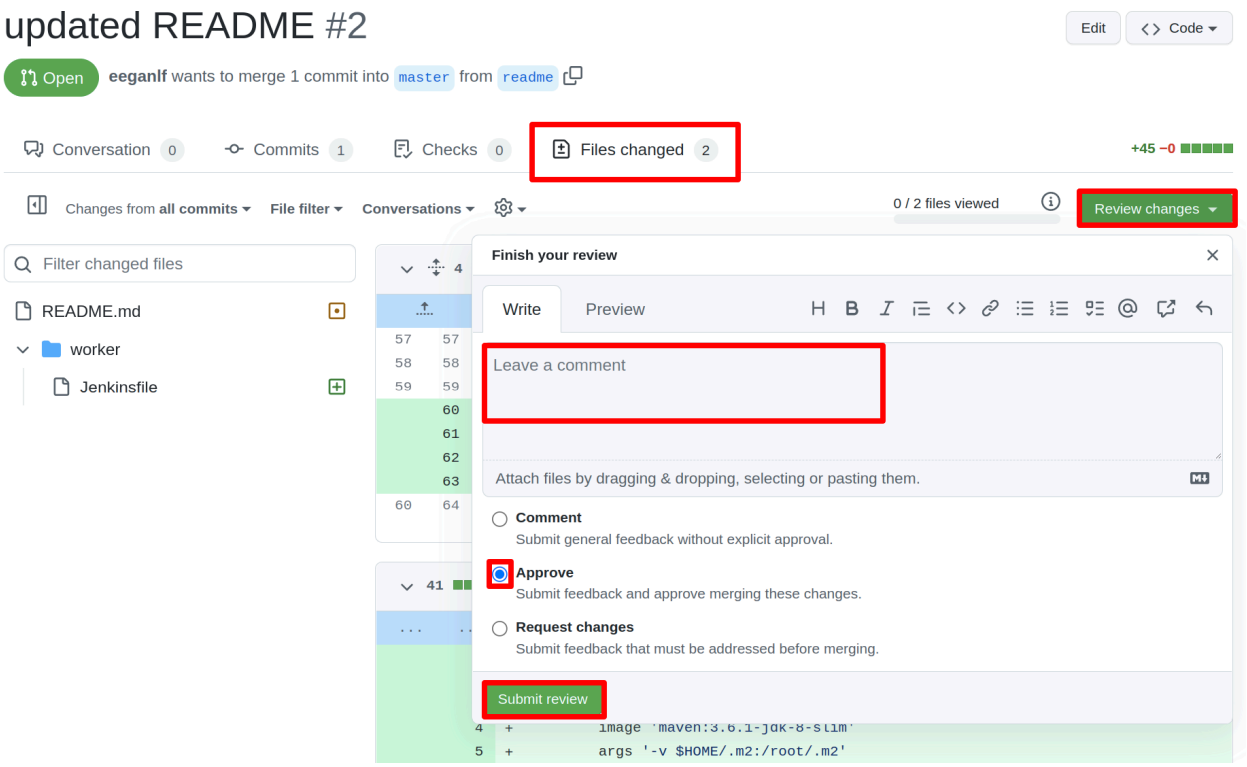
Add a reviewer: Creating a pull request does not allow you to merge immediately. It will require a code reviewer. This is mandated as part of the branch protection rules you created. Add at least one of your collaborators as a reviewer with the **Reviewers** gear icon:



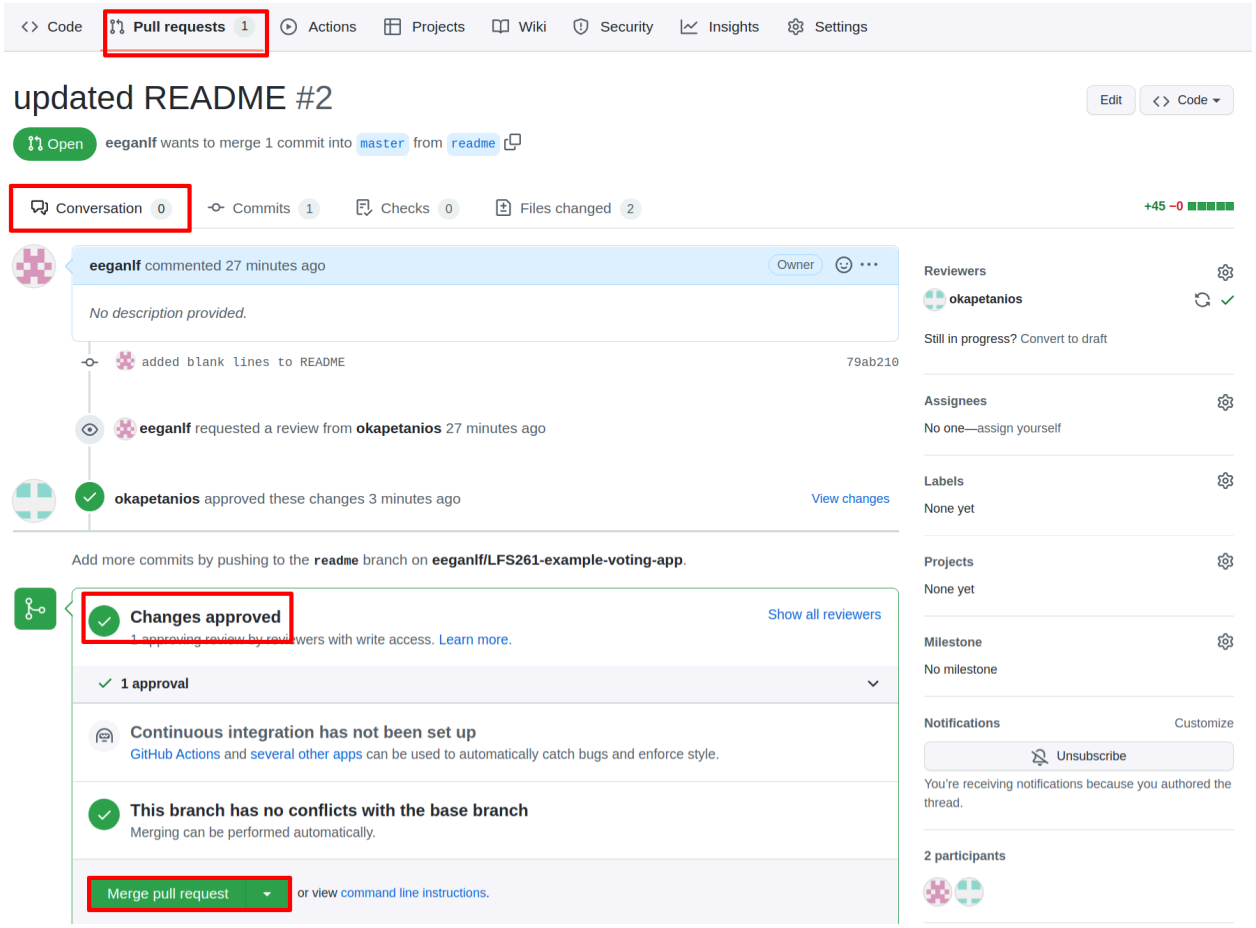
Approve a pull request as the reviewer. With the reviewer's account, visit the repository page, go to pull requests, and click on the pull request:



Review the changes, leave a comment if you wish, and approve the request by checking **Approve** and clicking **Submit Review**:



After approval, merge the pull request to master either from the reviewer's account or the requester's account. Go to **Pull requests > Conversation** and click **Merge pull request** as follows:



Delete the **`readme`** branch after the merge.

Writing Pipeline as Code

Resources:

- Declarative Pipeline Syntax
- Declarative Pipeline Steps

Some of the important instructions are:

- Pipeline
- Agent
- Tools
- Stages, Stage, Steps
- Post

Jenkinsfile for a Java Application

In this section, you will define pipeline as code for a Java worker app which uses Maven as a build tool.

Create a new `feature/workerpipe` branch by using the following commands:

```
git checkout -b feature/workerpipe
```

```
git branch
```

Now you are going to write a Jenkinsfile for the `worker` application.

Create a Jenkinsfile inside the `worker` directory of your code. Before you start writing the code, check your Maven version in your Jenkins: **Manage Jenkins > System Configuration > Tools > Maven Installations** and note down the exact name in the configuration (e.g. Maven 3.9.8).

```
pipeline {
  agent any

  tools{
    maven 'maven 3.9.8'

  }

  stages{
     stage("build"){
          steps{
               echo 'Compiling worker app'
               dir('worker'){
                 sh 'mvn compile'
               }
          }
     }
     stage("test"){
          steps{
               echo 'Running Unit Tests on worker app'

          }
     }
```

```
     stage("package"){
         steps{
             echo 'Packaging worker app'

         }
     }
 }

 post{
   always{
       echo 'Building multibranch pipeline for worker is completed..'
    }
  }
}
```

Once you create the Jenkinsfile, commit the file and push the changes to `feature/workerpipe`:

```
git status

git add worker/Jenkinsfile

git commit -am "added Jenkinsfile for worker with build job"

git push origin feature/workerpipe
```

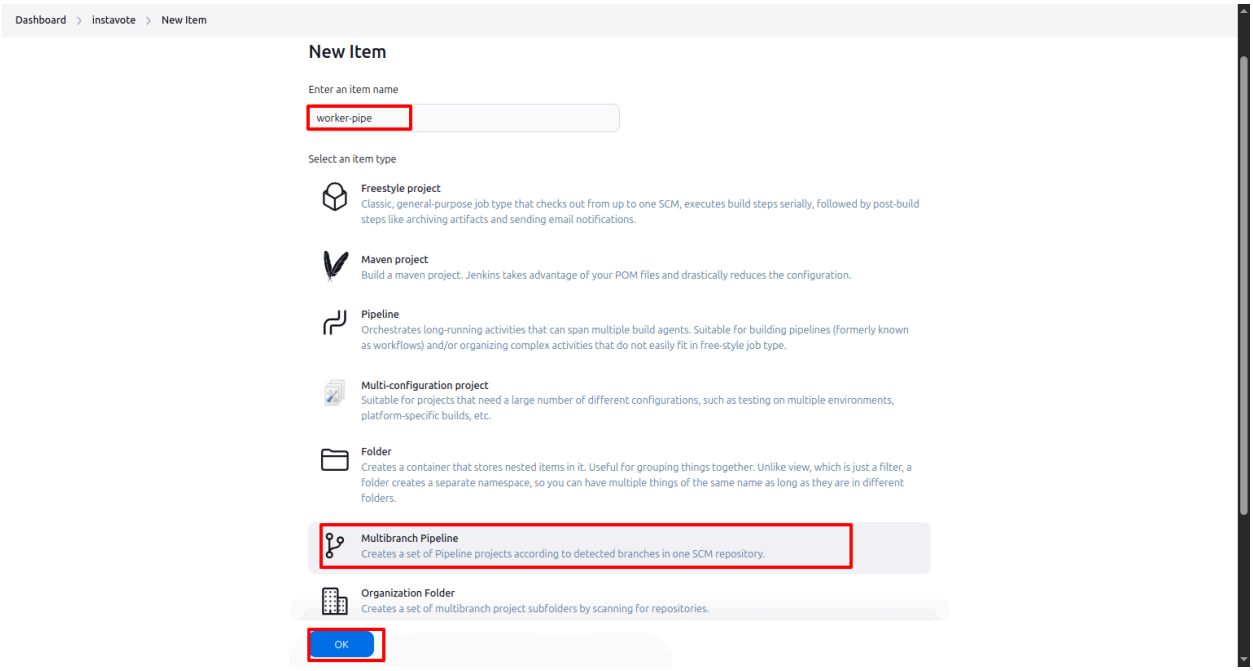
Multi-Branch Pipeline Project

In this section, you are going to create and execute a multi-branch pipeline which:

- Scans your repository automatically for a Jenkinsfile
- Sets up the pipeline jobs for the branches which contain the above pipeline script
- Starts executing the CI jobs

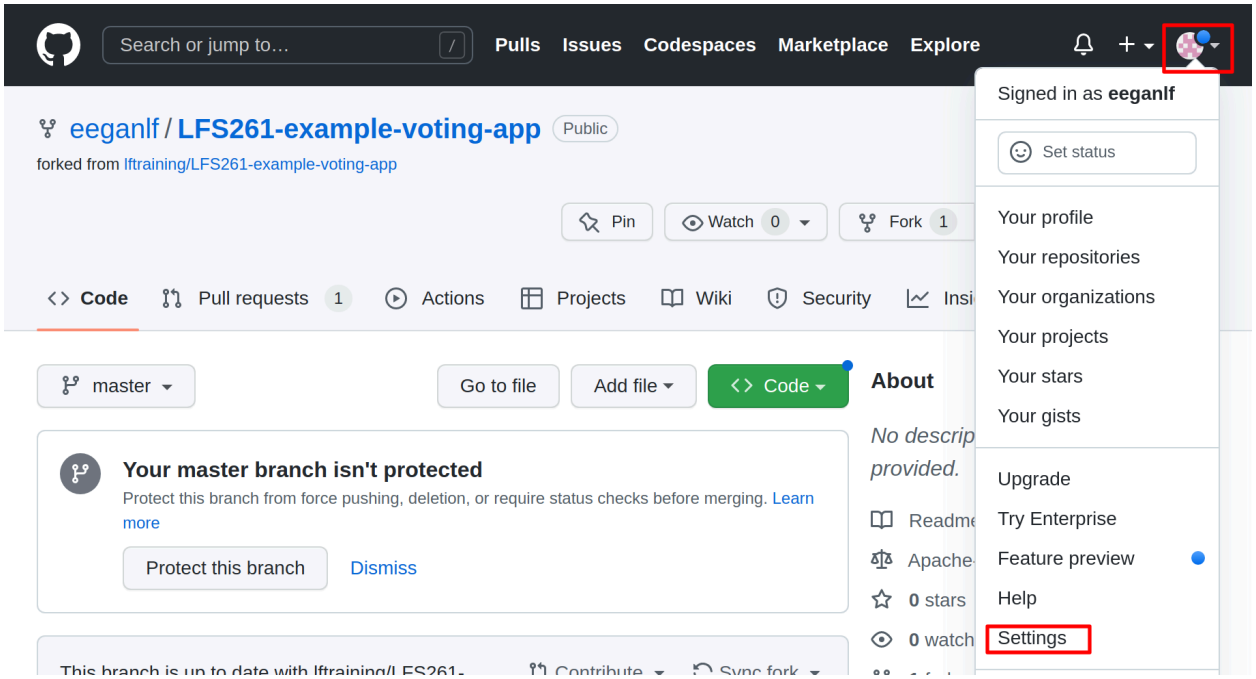
Refer to the following steps to create a multi-branch pipeline.

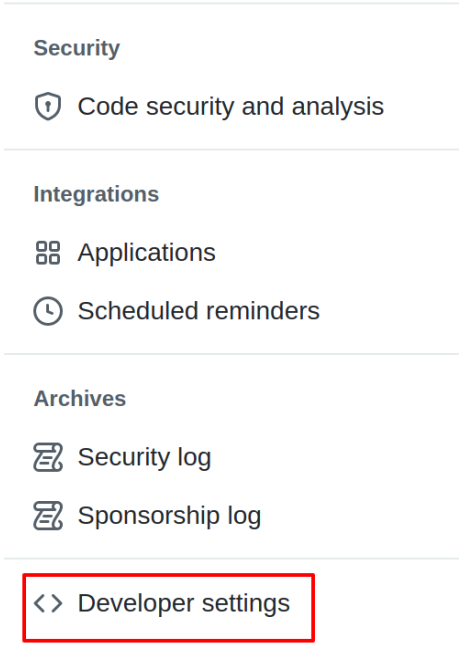
Create a new job **`worker-pipe`** in your **`instavote`** directory; select “Multibranch Pipeline” as the project type.



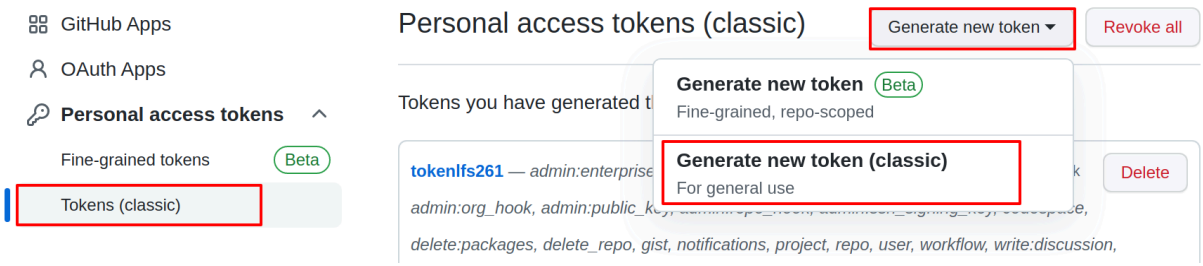
In the job configuration page, under the branch sources choose “GitHub”, add your account credentials, and choose the project repository. Refer to the images below for exact steps.

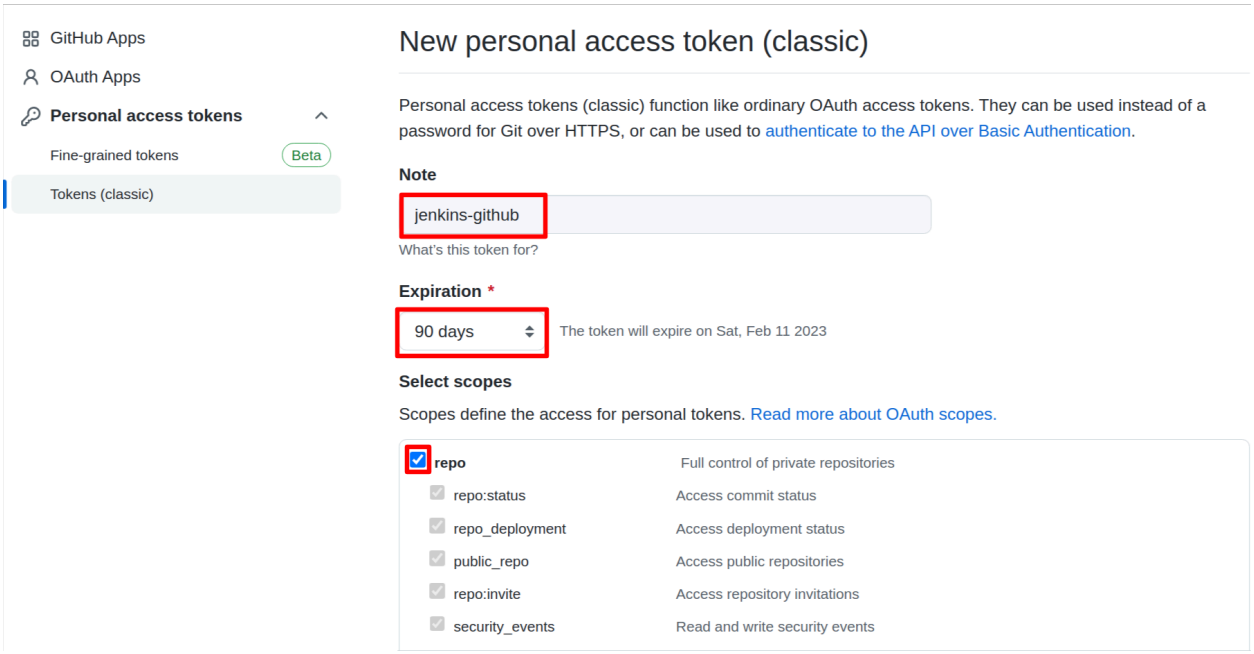
In a separate browser, navigate to **GitHub > Settings** and select **Developer Settings**.





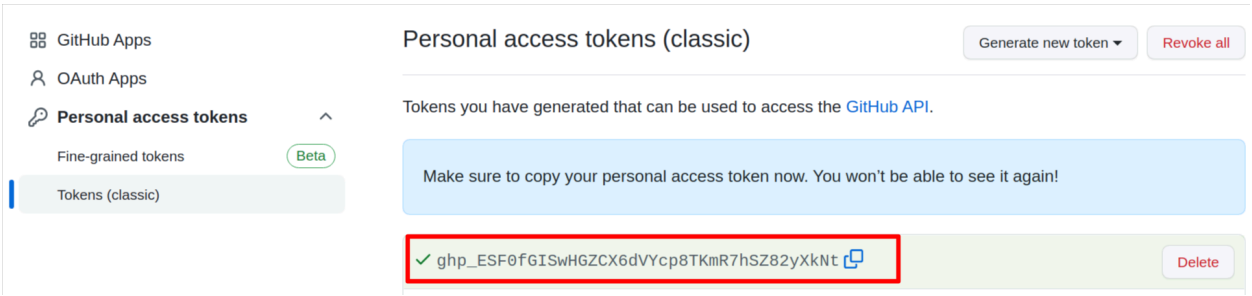
Generate a *personal access token* with access to **repo** enabled.



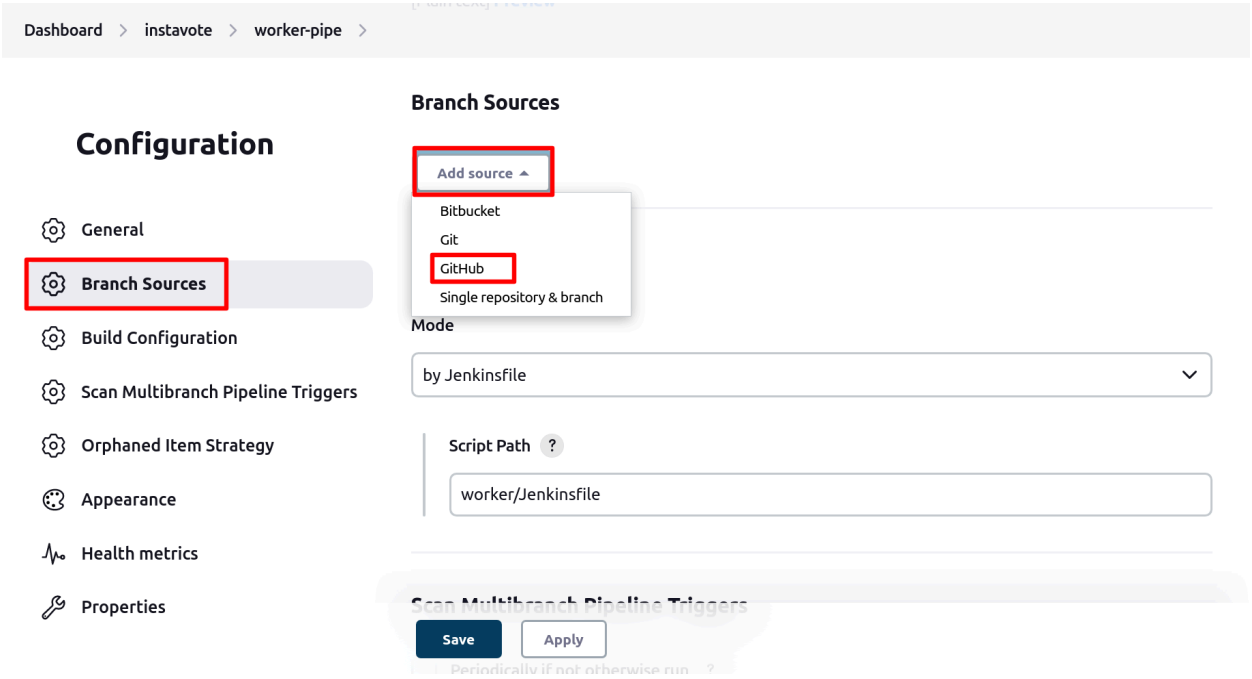


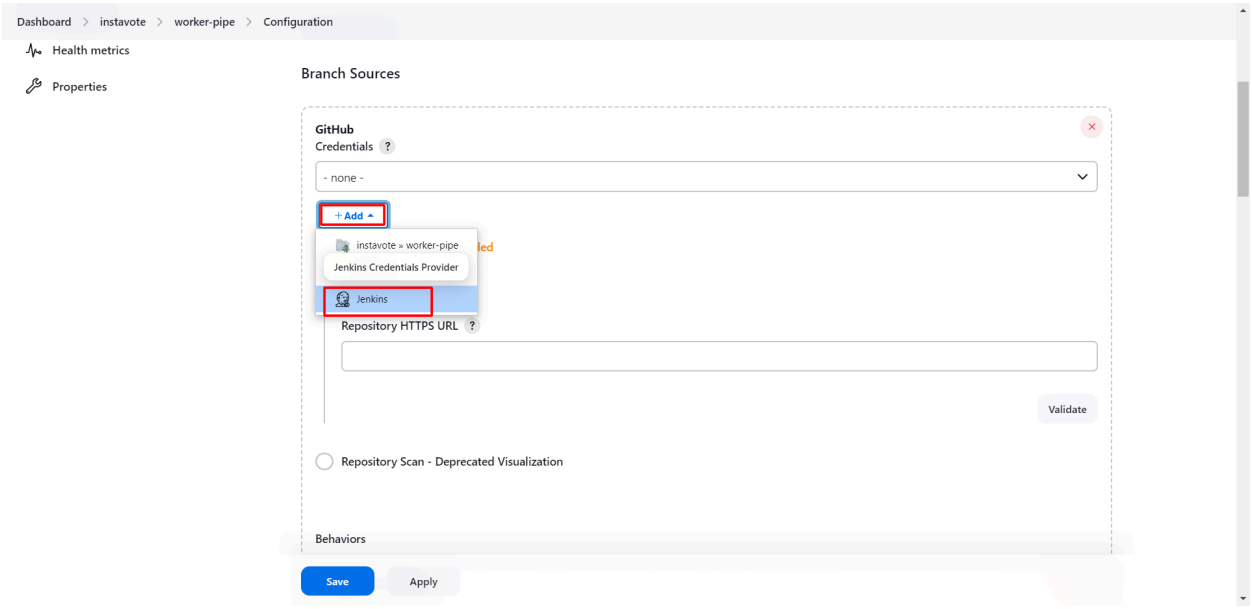
Click **Generate token** at the bottom of the page.

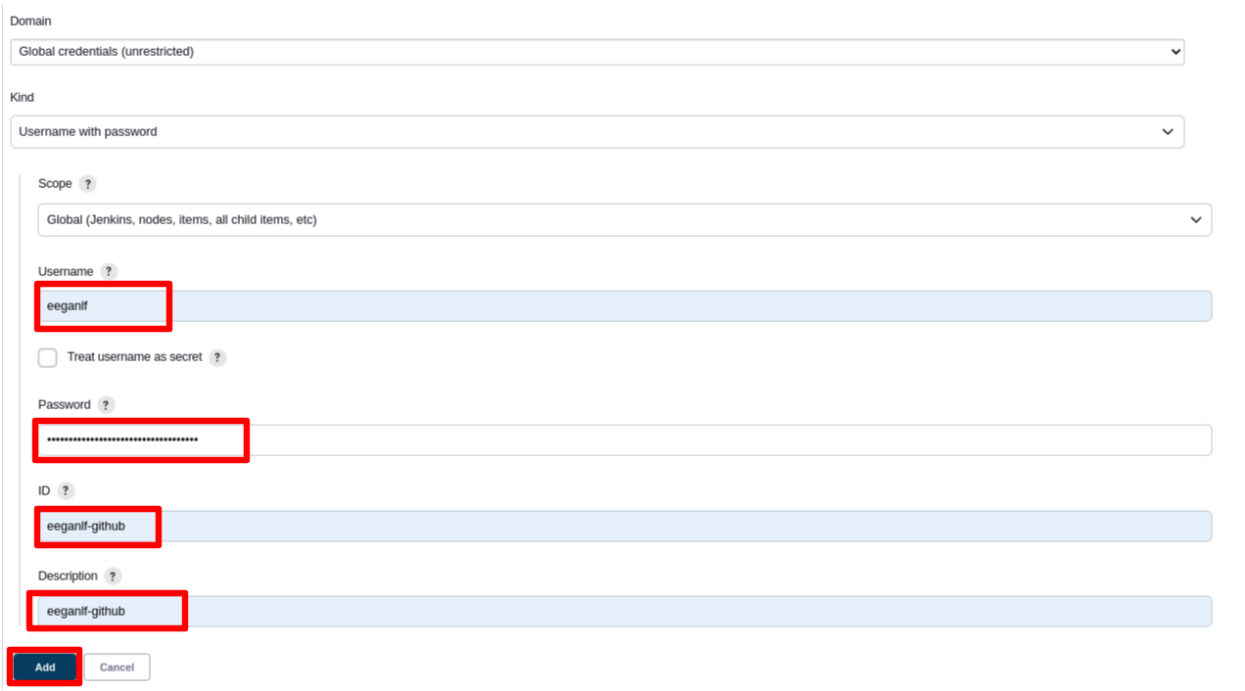
Copy the token:



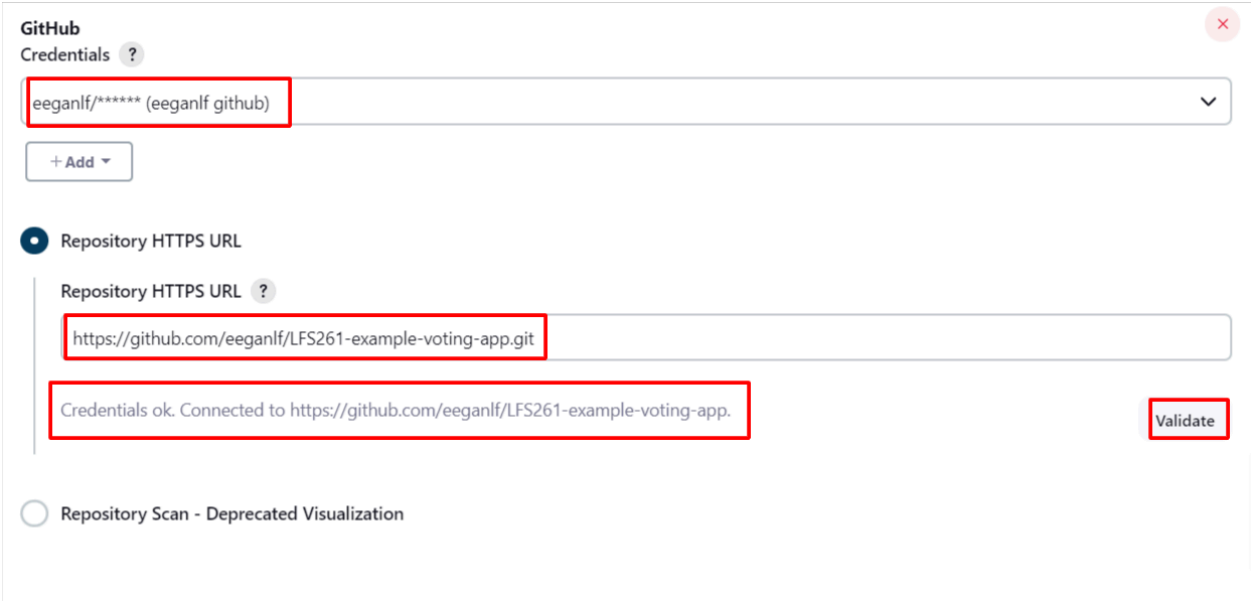
Return to the **`worker-pipe`** configuration page in Jenkins and configure the credentials. Be sure to use “Username and Password” and provide the token as the password, not the password you use to login to GitHub.



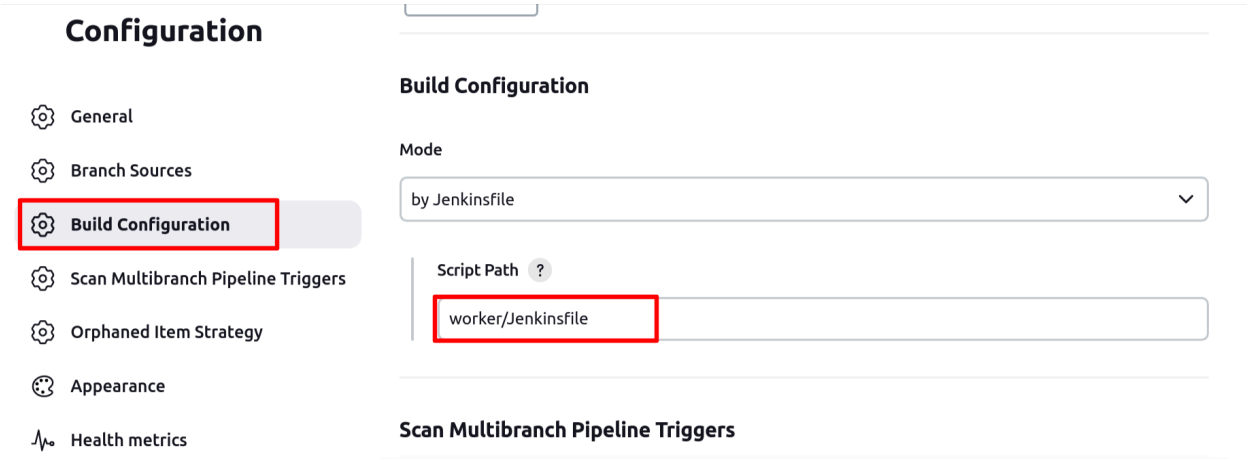




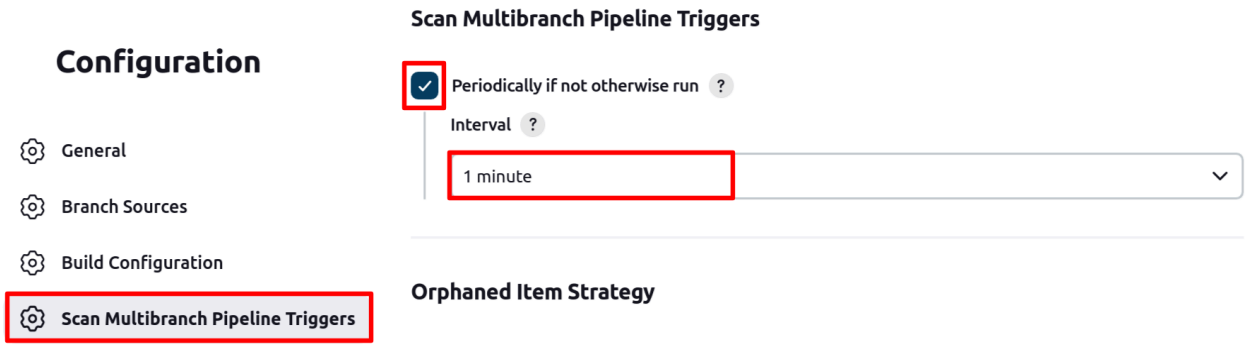
Under **Branch Sources** click **Add source** and select **GitHub.**

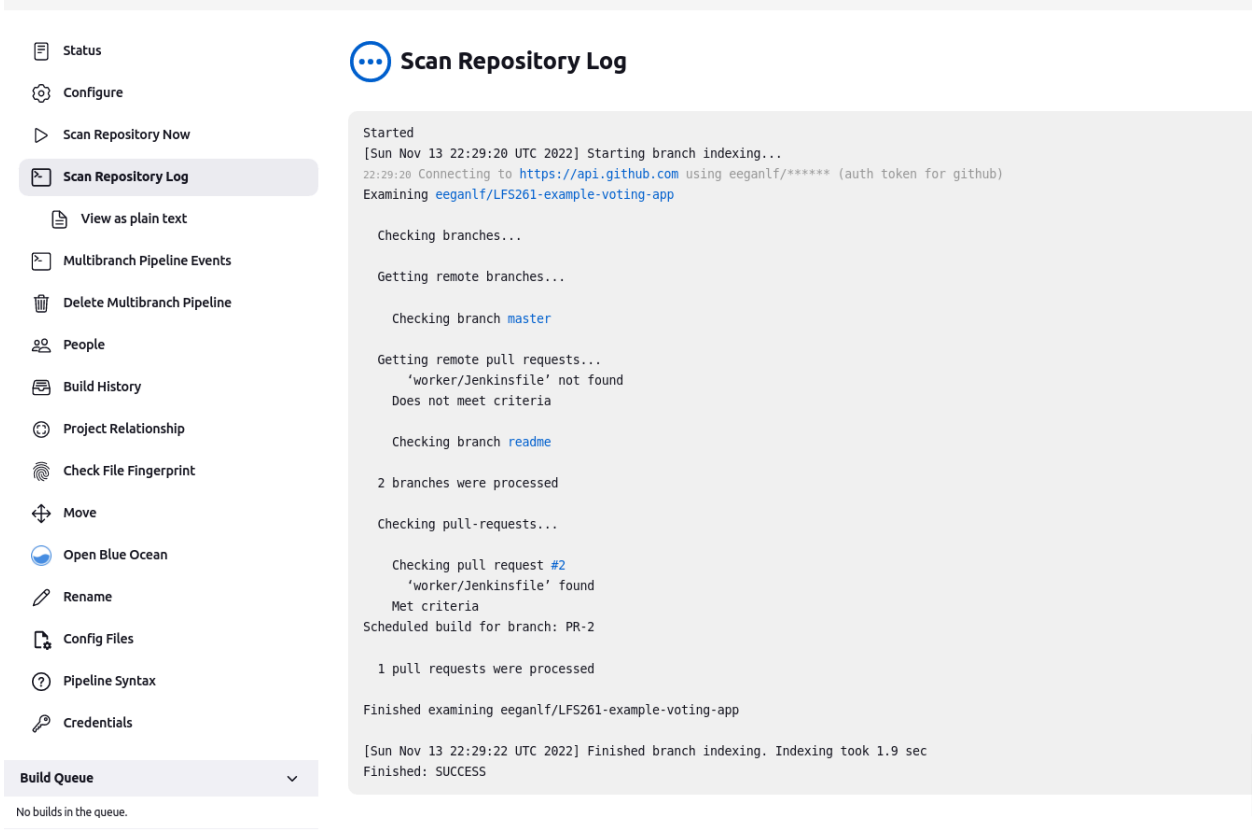


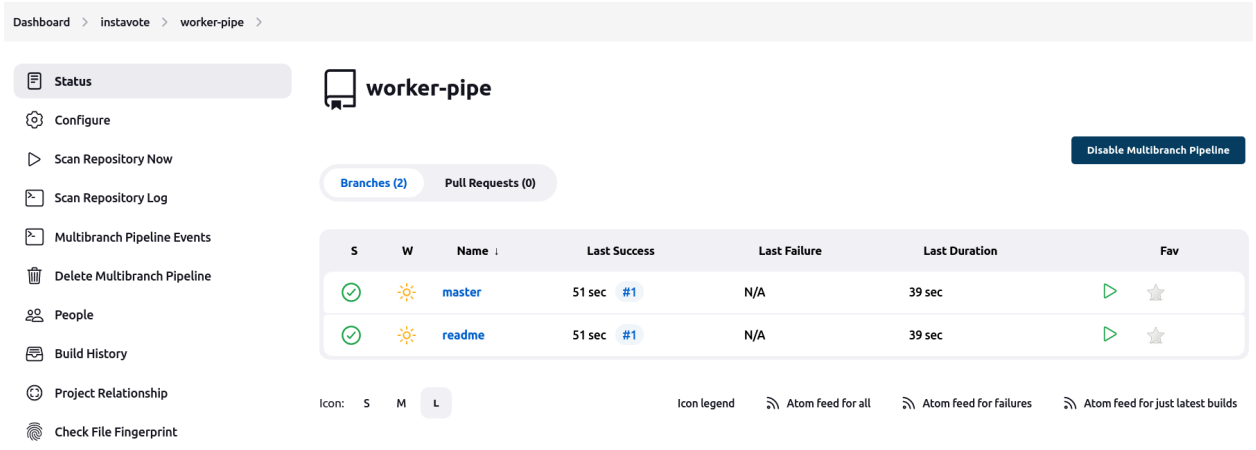
Under **Build Configuration**, input your Jenkinsfile path as `worker/Jenkinsfile` inside the **Script Path** input box.

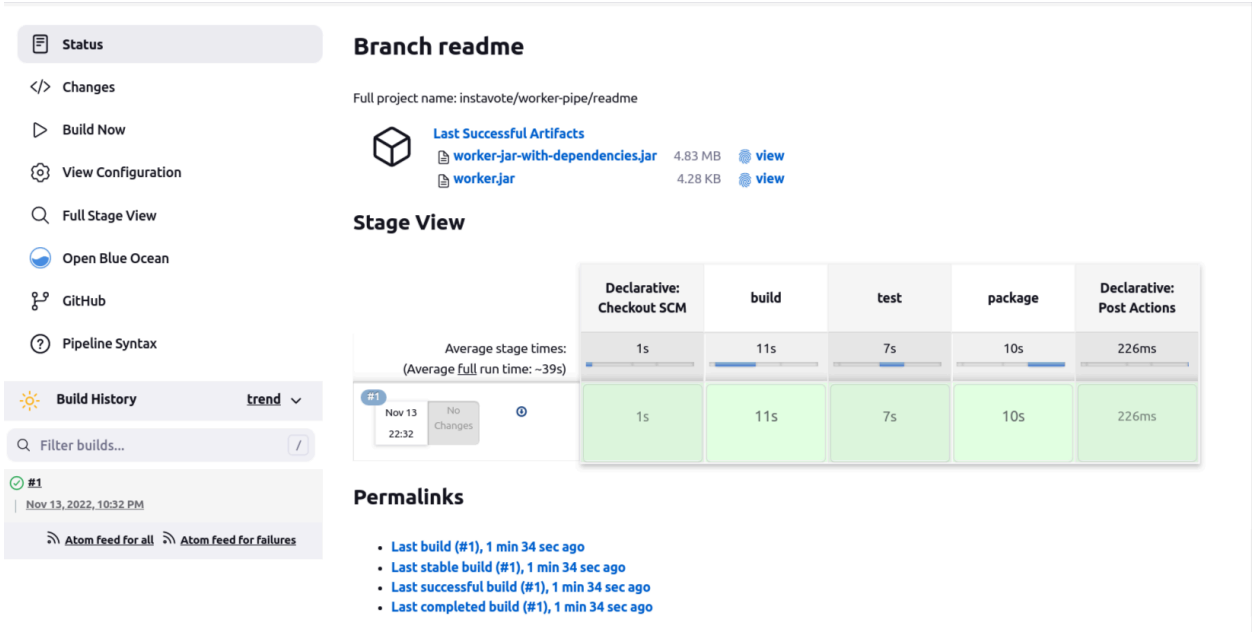


Select “1 minute” from the **Interval** drop down under **Scan Multibranch Pipeline Triggers** and **Save** the configuration.









It will automatically scan your repository. Whenever it detects a new branch under the repository, it runs the pipeline build automatically.

Once the pipeline run is successful, add two more stages in the same Jenkinsfile that contain two more commands: `mvn clean test` and `mvn package`:

```
pipeline {
  agent any

  tools{
    maven 'maven 3.9.8'

  }

  stages{
      stage("build"){
          steps{
              echo 'Compiling worker app..'
              dir('worker'){
                sh 'mvn compile'
              }
          }
      }
      stage("test"){
          steps{
              echo 'Running Unit Tests on worker app..'
              dir('worker'){
```

```
                sh 'mvn clean test'
            }
        }
    }
    stage("package"){
        steps{
            echo 'Packaging worker app'
            dir('worker'){
              sh 'mvn package'
            }

        }
    }
  }

  post{
    always{
        echo 'Building multibranch pipeline for worker is completed..'
    }
  }
}
```

After making changes in Jenkinsfile, commit the file from your `feature/workerpipe` and push the changes into the same branch:

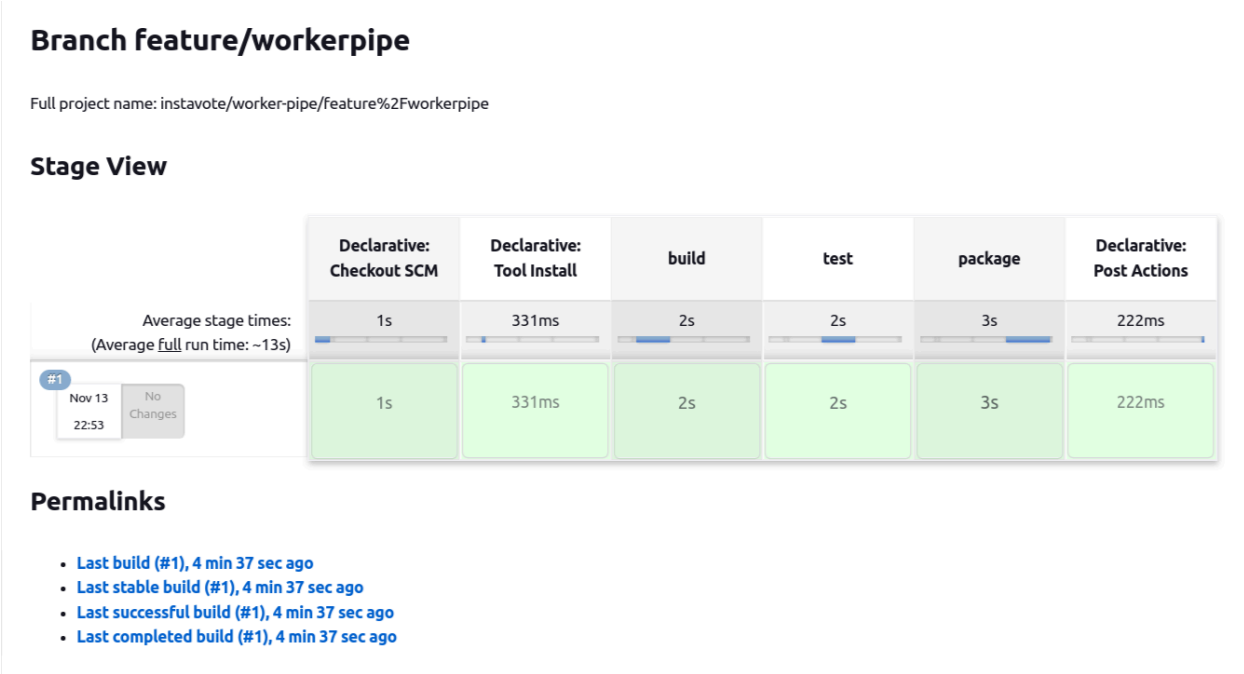
```
git status

git add worker/Jenkinsfile

git commit -am "added Test and package job for worker pipeline"

git push origin feature/workerpipe
```

Once you push the changes to the `feature/workerpipe` branch, the scan will automatically trigger the `feature/workerpipe` branch build in the `instavote` multibranch pipeline.

After running the package, it will create a jar/war file. You need to archive that artifact.

```
pipeline {
  agent any

  tools{
    maven 'maven 3.9.8'

  }

  stages{
      stage("build"){
```

```
          steps{
              echo 'Compiling worker app..'
              dir('worker'){
                sh 'mvn compile'
              }
          }
      }
      stage("test"){
          steps{
              echo 'Running Unit Tests on worker app..'
              dir('worker'){
                sh 'mvn clean test'
              }

          }
      }

      stage("package"){
          steps{
              echo 'Packaging worker app'
              dir('worker'){
                sh 'mvn package -DskipTests'
              }

          }
      }
  }

  post{
    always{
        archiveArtifacts artifacts: '**/target/*.jar', fingerprint:
true

echo 'Building multibranch pipeline for worker is completed..'
    }
  }
}
```



Commit the changes to **`feature/workerpipe`** and push to the branch:

```
git status

git add worker/Jenkinsfile

git commit -am "archive artifacts, skip test and package"

git push origin feature/workerpipe
```

You have set up a multibranch pipeline so that the CI pipelines are run automatically for every branch that you create in future. This is extremely useful to get the feedback from the CI system, before you merge the code into the trunk. This helps ensure that the master branch is never broken.

Configuring Conditional Execution of Stages

With the current configuration, the pipeline you have created will launch for any and every change committed to the repository. However, it makes sense to restrict this behavior to changes made for the **`worker`** application. This is a desirable feature with mono repositories that contain multiple subprojects.

You may also want to restrict certain jobs to run only on specific branches. For example, integration and acceptance tests should run only for changes to the master branch, and

packaging applications to create and distribute artifacts should only run for the master branch.

This is achieved by setting up conditional execution. You are going to define the following conditions for the **worker** pipeline:

- Run packaging jobs only on master
- Run the jobs in this pipeline only if the code in the **worker** subdirectory is updated

Read the description of the **when** directive in the Jenkinsfile documentation for reference, then refactor the code as follows:

```
pipeline {
  agent any

  tools{
    maven 'maven 3.9.8'

  }
  stages{
      stage("build"){
        when{
            changeset "**/worker/**"
          }

        steps{
          echo 'Compiling worker app..'
          dir('worker'){
            sh 'mvn compile'

          }
        }
      }
      stage("test"){
        when{
          changeset "**/worker/**"
        }
        steps{
          echo 'Running Unit Test on worker app..'
          dir('worker'){
            sh 'mvn clean test'
           }

          }

      }
      stage("package"){
        when{
          branch 'master'
```

```
          changeset "**/worker/**"
        }
        steps{
          echo 'Packaging worker app'
          dir('worker'){
            sh 'mvn package -DskipTests'
            archiveArtifacts artifacts: '**/target/*.jar',
fingerprint: true  }

        }

      }
  }

  post{
    always{
        echo 'Building multibranch pipeline for worker is completed..'
    }

  }

}
```

Once you make changes, commit the changes to **`feature/workerpipe`** and push to GitHub:

```
git status

git add worker/Jenkinsfile

git commit -am "run package step only on master, run stages only when
worker changes"

git push origin feature/workerpipe
```

After making these changes, you will notice that the build will run only for the first two stages and skip the package stage.

***WARNING**: Even though Jenkinsfile is part of the **`worker`** subpath, it's not considered to be part of the changeset to trigger the builds. You will need to make changes to other files in order to see the jobs being triggered.*

You can make some changes in the **`README.md`** file in the root directory, commit those changes, and push to **`feature/workerpipe`**. The build will be triggered, but it will skip all three stages.

Use **`git log`** and **`reset`** to go back to your previous commit:

```
git log
```

```
git reset --hard yourlastcommitid

git push origin feature/workerpipe -f
```

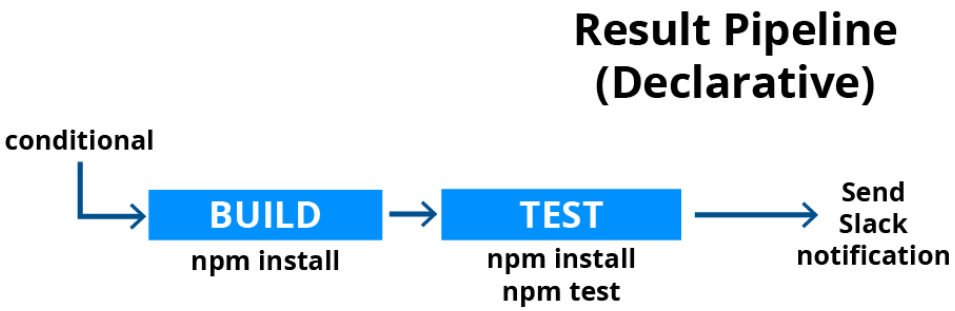
You have learned how to use conditional pipeline stages.

Once you are done with the work, don't forget to incorporate these changes into the master branch via a **pull request** and delete the feature branch.

Exercise: Writing a Jenkinsfile for the Result NodeJS Application

You have been tasked to write a declarative pipeline for the `result` application:

- Two stages, build and test
- Stages should run conditionally only when there is a change to the `result` subdirectory
- You can refer to the following workflow:



The solution to this exercise will be provided as a separate document. Refer to it to validate once you have attempted it yourself.

Summary

We learned how to write a pipeline using declarative code in this lab. We also learned how to enforce workflows through GitHub, create multi-branch pipelines, and add conditional stages.

Lab 5S. Solution to the Jenkinsfile Exercise

With this exercise, you will create a **result** declarative pipeline for a NodeJS application and a multi-branch Jenkins project to build and test it.

Writing A Jenkinsfile for a NodeJS Application

Create a branch **feature/resultpipe** using the **git checkout** command:

```
git checkout -b feature/resultpipe
```

Create a Jenkinsfile inside the **result** directory or copy the previous **Jenkinsfile** file from **worker** into **result**.

In the **result/Jenkinsfile**, add Node.js tools with the exact version that is configured in **Manage Jenkins > System Configuration > Tools > Nodejs Installations**.

Paste the following code into your Jenkinsfile:

```
pipeline {
  agent any

  tools{
    nodejs 'NodeJS 22.4.0'

  }

  stages{
      stage(build){
        when{
            changeset "**/result/**"
          }

        steps{
          echo 'Compiling result app..'
```

```
            dir('result'){
              sh 'npm install'
            }
          }
        }
        stage(test){
          when{
            changeset "**/result/**"
          }
          steps{
            echo 'Running Unit Tests on result app..'
            dir('result'){
              sh 'npm install'
              sh 'npm test'
             }

            }

        }

    }

}
```

Now you have a Jenkinsfile that installs and tests npm, and it will also send a Slack notification if you have completed that lab. Commit and push the changes into **`feature/resultpipe`** on GitHub using the following commands. This will automatically run the pipeline:

```
git status

git add result/Jenkinsfile

git commit -am "adding Jenkinsfile for result app"

git push origin feature/resultpipe
```

On Jenkins, create a new multibranch pipeline called **`result-pipe`** and copy from **`worker-pipe`**. Go to your **`result-pipe`** configuration page, name it **`result-pipe`**, add the description **instavote result multi branch pipeline** and, under **Build Configuration**, change the script path to **`result/Jenkinsfile`**. **Save** the configuration page to create the project. Observe it as it scans your repository and starts the build.

Go to **`result/test/mock.test.js`** file and add one more mock test by copying and pasting an existing test block. Commit the changes to the **`feature/resultpipe`** branch using the following commands:

```
git status

git add result/Jenkinsfile

git commit -am "adding mock test"

git push origin feature/resultpipe
```

Create a pull request on your GitHub account and merge it with the master branch. Once merged, Jenkins will run pipeline jobs for master. Disable the jobs **`worker-build`** and **`result-build`** via their respective configuration pages. These do not need to run anymore.

In this exercise, you learned how to create a Jenkinsfile for a Node.js application.

Common Issues

If you see the following error as part of the test job run on Jenkins:

```
+ npm test

> result@1.1.0 test /var/jenkins_home/workspace/e_result
pipe_feature_resultpipe/result
> mocha

sh: 1: mocha: not found
npm ERR! Test failed. See above for more details.
```

Ensure that you have added **`npm install`** as part of the test stage:

```
stage(test){
   when{
     changeset "**/result/**"
   }
   steps{
     echo 'Running Unit Tests on result app..'
     dir('result'){
       sh 'npm install'
       sh 'npm test'
      }

     }
   }
 }
```

Lab 5.1. Pipeline as Code (Additional Topics)

After creating a Jenkinsfile and a multi-branch project to build the Java application, you can additionally configure integration with Slack and send notifications related to builds right from the Jenkinsfile.

Integrating Slack with Jenkins

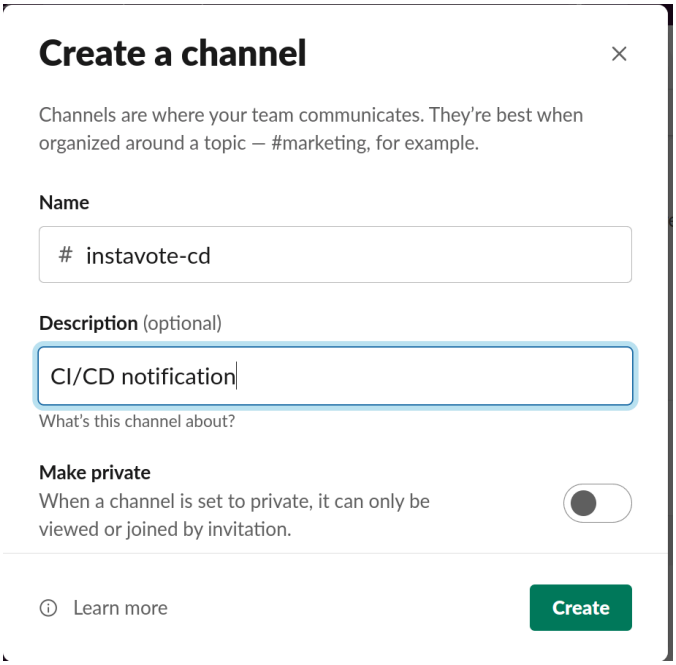
***NOTE**: This is an optional section. Refer to it only if you wish to integrate with Slack for notifications.*

You will learn how to integrate Slack with Jenkins. This will be helpful to send notifications related to your build from Jenkins to a Slack channel.

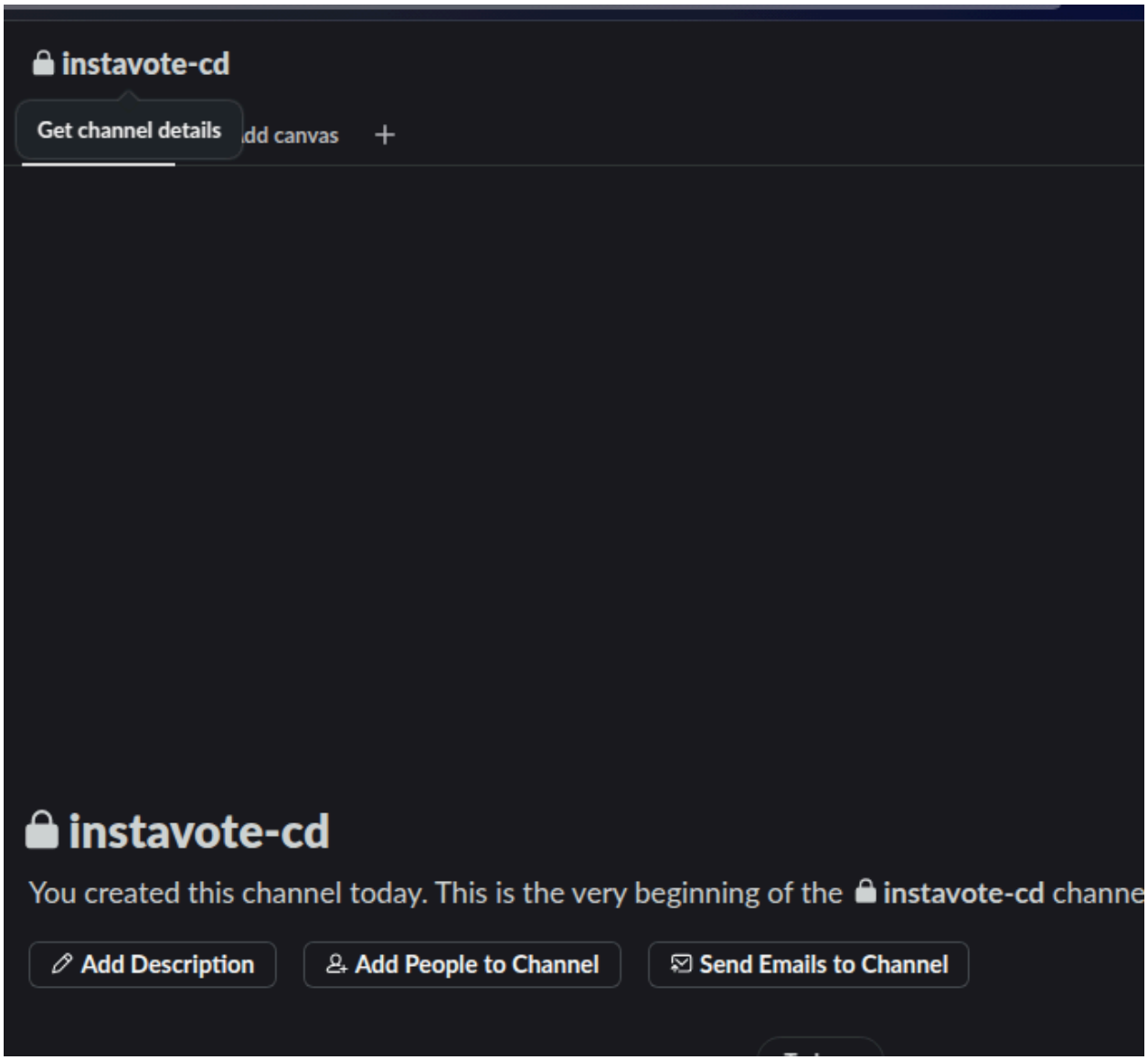
As a prerequisite for this, you need a Slack account. Additionally, you should be the Slack channel administrator.

Follow these steps to complete this setup.

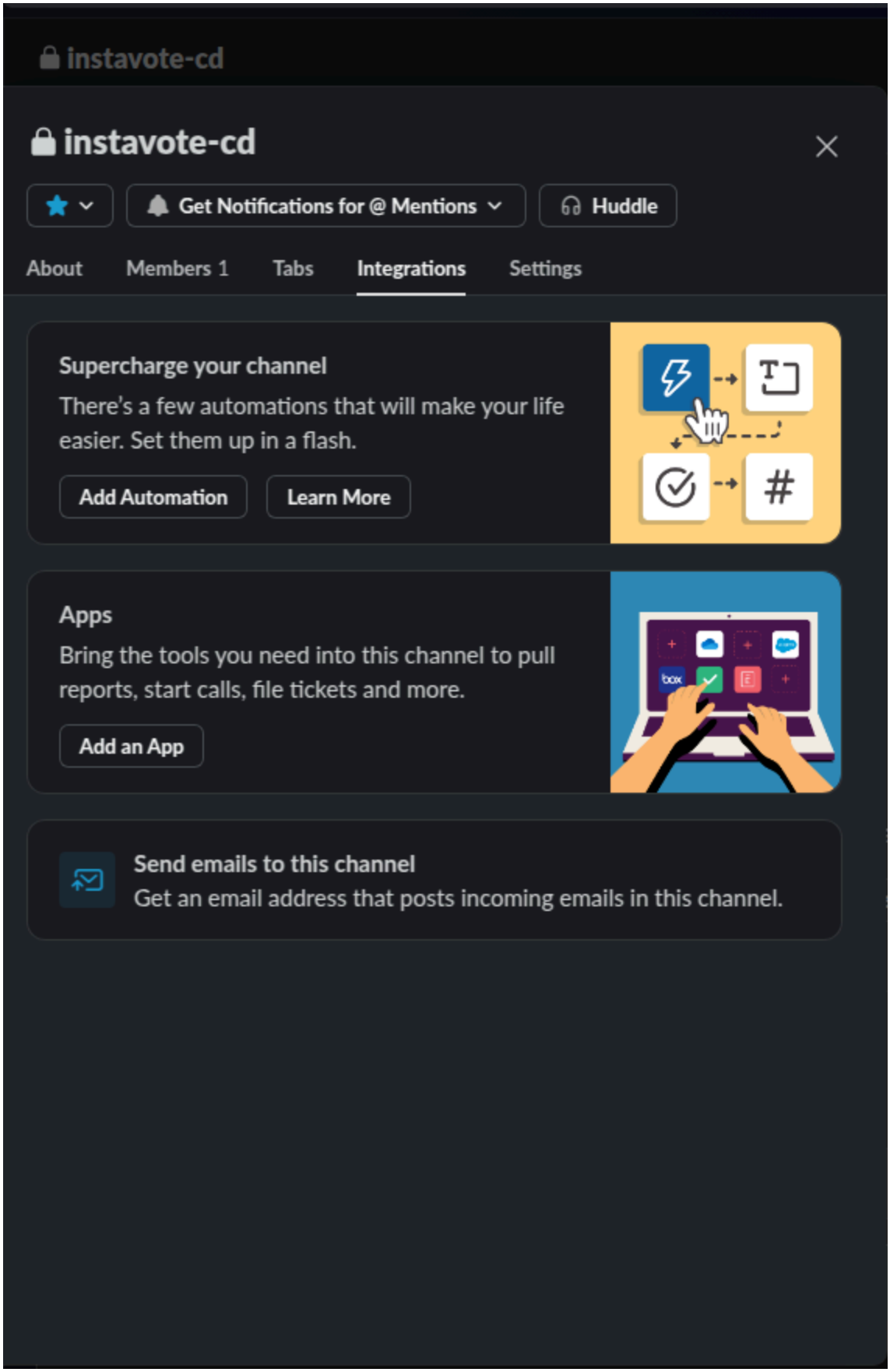
Create a Slack account and create a channel named **`#instavote-cd`**. You can find Slack documentation on creating a channel here.



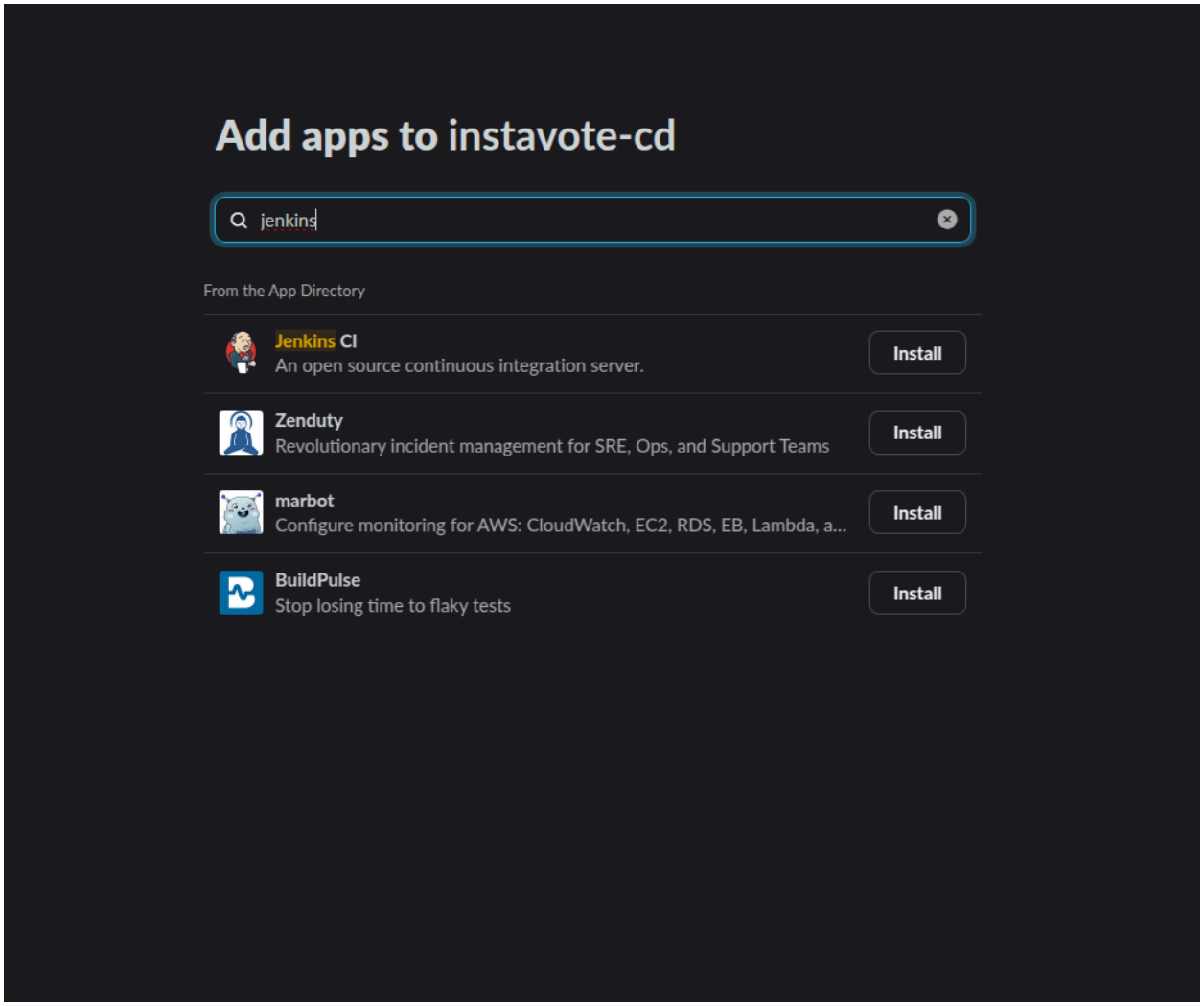
After creating the channel, go to the channel details by clicking the name of the channel.



Find the **Integrations** tab and click **Add an App.**

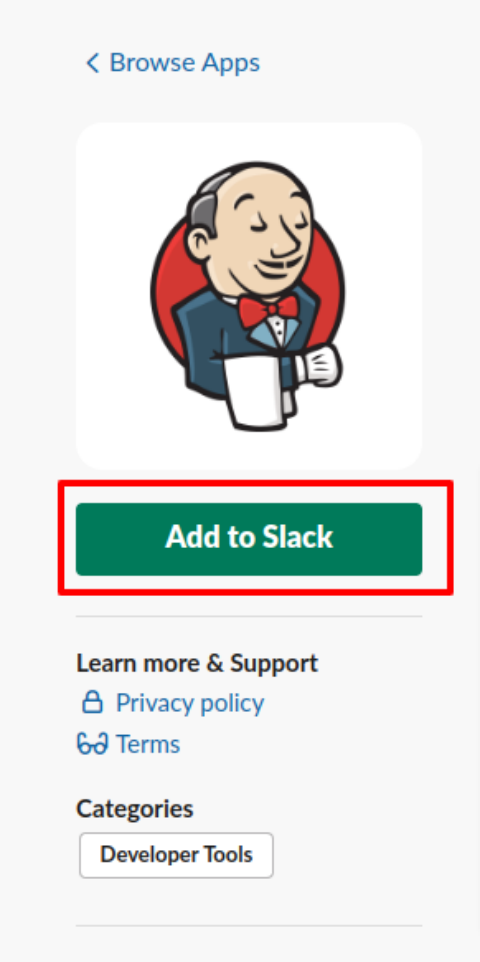


Search for “Jenkins CI” and select it.

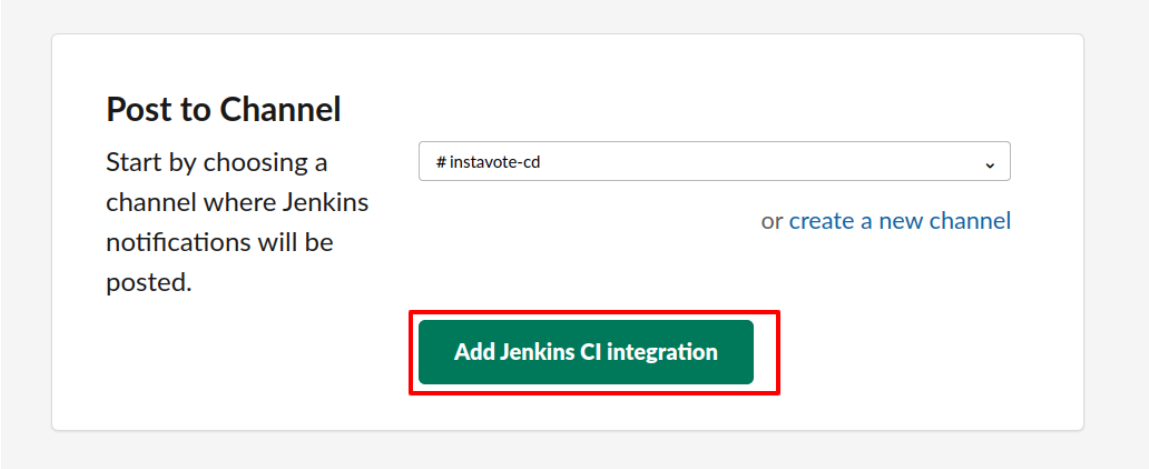


This will open a browser window.

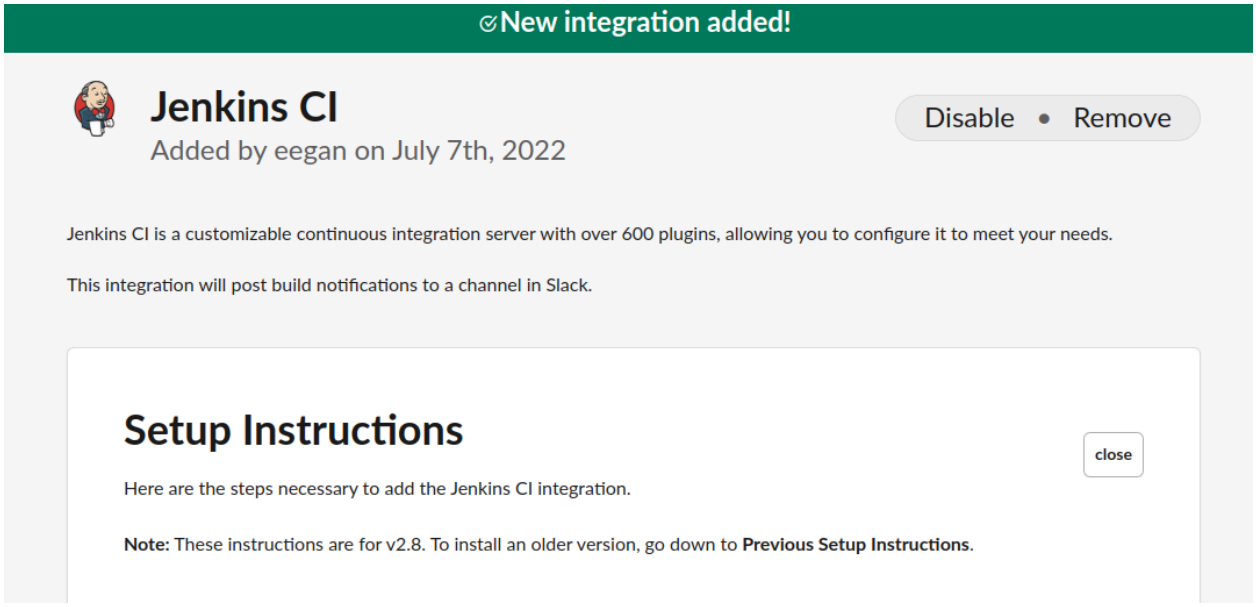
Click **Add to Slack.**



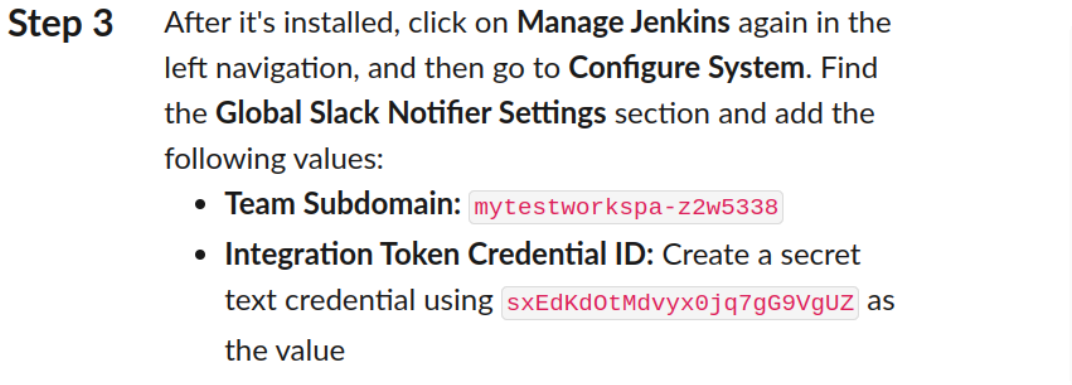
Choose the channel and click **Add Jenkins CI integration.**



Follow the **Setup Instructions** on this page:



You will be gathering the **Team Subdomain** and **Integration Token Credential ID** from this page, so leave it open.

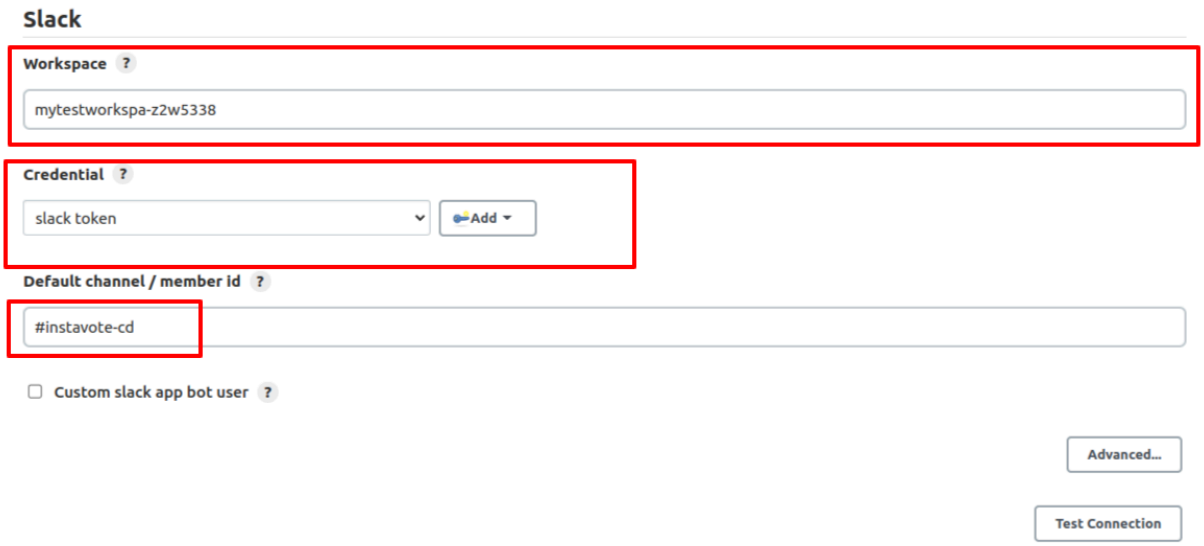


Go to your Jenkins, **Manage Jenkins > Manage Plugins > Available Plugins**, and search for the “Slack notification” plugin and install it without a restart.

Go to **Manage Jenkins > System**. At the bottom, you will find the *Slack* section. Paste your **Team Subdomain** into the **Workspaces** input box.

Click **Add** under **Credential**. Add the credential as secret text using the integration token credential ID given in the Slack-Jenkins setup instructions in previous steps.

Add your **Default channel / member id** as **`#instavote-cd`** (or whatever you named your channel in Slack) and save the configuration.



From the Slack configuration page, click to save the configuration.

From your Jenkins account, choose any job and go to the configuration page. Add the Slack notification as the post-build action. Save and build the job. Now your notifications should show up in your Slack channel.

Sending Notifications from a Pipeline Job

You can add Slack notifications to any pipeline job with the **`slackSend`** directive. You will have to set up the integration as described above before you attempt this.

Below is a code snippet which demonstrates how to achieve this. The entire Jenkinsfile can be found here: https://raw.githubusercontent.com/lftraining/LFS261-example-voting-app/refs/heads/master/gists/lab5.1_worker_jenkinsfile_slack_integration.

```
file: worker/Jenkinsfile

pipeline {
  agent any
```

```
  tools{
    maven 'maven 3.9.8'

  }

  stages{
      stage(build){
        when{
            changeset "**/worker/**"
          }

        steps{
          echo 'Compiling worker app..'
          dir('worker'){
            sh 'mvn compile'
          }
        }
      }
      stage(test){
        when{
          changeset "**/worker/**"
        }
        steps{
          echo 'Running Unit Tests on worker app..'
          dir('worker'){
            sh 'mvn clean test'
            }

          }
      }
      stage(package){
        when{
          branch 'master'
          changeset "**/worker/**"
        }
        steps{
          echo 'Packaging worker app'
          dir('worker'){
            sh 'mvn package -DskipTests'
            archiveArtifacts artifacts: '**/target/*.jar',
fingerprint: true  }

        }
      }
  }

  post{
```

```
    always{
        echo 'Building multibranch pipeline for worker is completed..'
    }
    failure{
      slackSend (channel: "instavote-cd", message: "Build Failed - $
{env.JOB_NAME} ${env.BUILD_NUMBER} (<${env.BUILD_URL}|Open>)")   }

 success{
      slackSend (channel: "instavote-cd", message: "Build Succeeded -
$ {env.JOB_NAME} ${env.BUILD_NUMBER} (<${env.BUILD_URL}|Open>)")
    }

  }

}
```

Once you make changes in the Jenkinsfile, commit and push to the `feature/workerpipe` branch:

```
git status

git add worker/Jenkinsfile

git commit -am "add slack notifications"

git push origin feature/workerpipe
```

After pushing the changes to the branch, the pipeline will build automatically and send a notification to Slack. From Slack, you will get a link to visit the build status of your job.

Since this feature is complete, it is time to merge it all into the master. Once merged, don't forget to delete the branch from the remote repo, as well as from your local workspace.

Lab 6. Using Docker with Jenkins Pipelines

By the end of this lab exercise, you should be able to:

- Prepare the Jenkins environment to build with a Docker agent
- Refactor a Jenkinsfile with a Docker-based agent

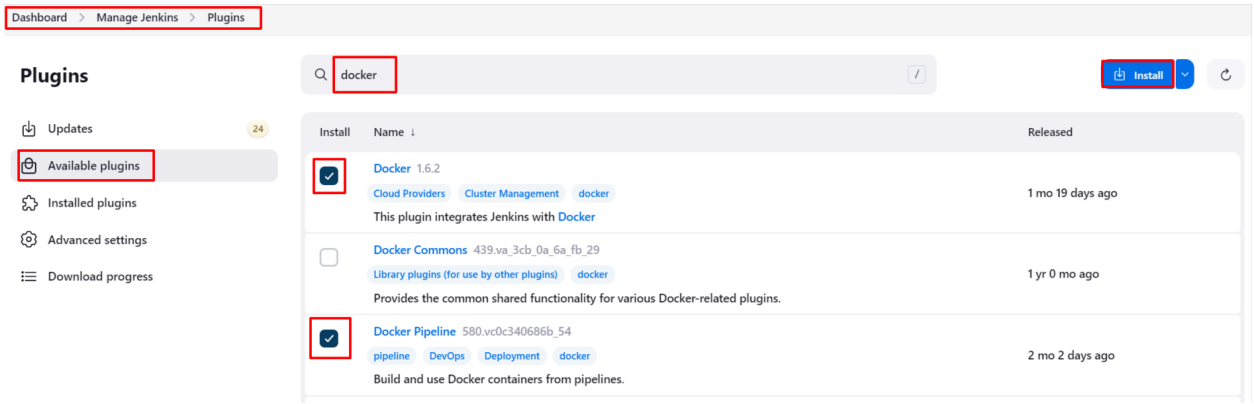
Steps:

- Read *"Using Docker with Pipeline"*
- Refactor the Jenkinsfile for the **`worker`** application

Install Docker Plugins

Install the following plugins:

- Docker Plugin
- Docker Pipeline



Refer to the screenshot above to choose the correct plugins and proceed with the installation.

Refactoring the Worker Pipeline to Build with Docker Agent

Create a new branch to make changes.

```
git checkout -b feature/dockerbuild
```

Now update the Jenkinsfile for the **worker** app:

- Remove the **tools** section
- Change the agent configuration from **any** to **docker**
- Provide the Docker agent configurations with
    - image: **maven:3.9.8-sapmachine-21**
    - args: **'-v $HOME/.m2:/root/.m2'**

Your **worker/Jenkinsfile** should contain the following:

```
pipeline {

    agent{
       docker{
         image 'maven:3.9.8-sapmachine-21'
         args '-v $HOME/.m2:/root/.m2'
       }

    }

    stages{
        stage('build'){
            steps{
                echo 'building worker app'
                dir('worker'){
                  sh 'mvn compile'
                }
            }
        }
        stage('test'){
            steps{
                echo 'running unit tests on worker app'
                dir('worker'){
                  sh 'mvn clean test'
                }
            }
        }
```

```
        stage('package'){
            steps{
                echo 'packaging worker app into a jarfile'
                dir('worker'){
                  sh 'mvn package -DskipTests'
                  archiveArtifacts artifacts: '**/target/*.jar',
fingerprint:  true
                }
            }
        }
    }
    post{
        always{
            echo 'the job is complete'
        }

    }

}
```

Once you have modified the file, commit the changes:

```
git commit -am "add docker based agent"

git push origin feature/dockerbuild
```

Jenkins launches the pipeline, this time with Docker as an agent.

Validation

While the job is running, log into the Docker DIND Host and watch for the container which gets launched when the pipeline starts and stays till the end of the build. Switch into **devops-repo/setup**:

```
$ docker compose exec docker sh
$ watch docker ps

...
...
[observe the container running while the pipeline is in progress]
...
..
[^c followed by ^d to stop the watch command and exit from the
container]
```

You should see containers being launched periodically by Jenkins. You can also observe the console logs for the pipeline to see a container being launched, then stopped, and finally removed as part of the build process. You can always view the pipeline console output by clicking the build number and clicking **Console Output** on the menu on the right.

Once you've done this, remember to merge the changes into the master branch via a pull request and then delete the feature branch from remote (GitHub) and locally.

Summary

In this lab, we built a simple Docker pipeline to ensure that Docker was working on Jenkins. We refactored our **`worker`** application Jenkinsfile so that the pipeline would run on Docker.

Lab 7. Packaging with Docker

In addition to helping with the process of building and testing software, Docker can also provide a standard packaging format with Docker images. This packaging format comes with the distribution mechanism, i.e., Docker image registries.

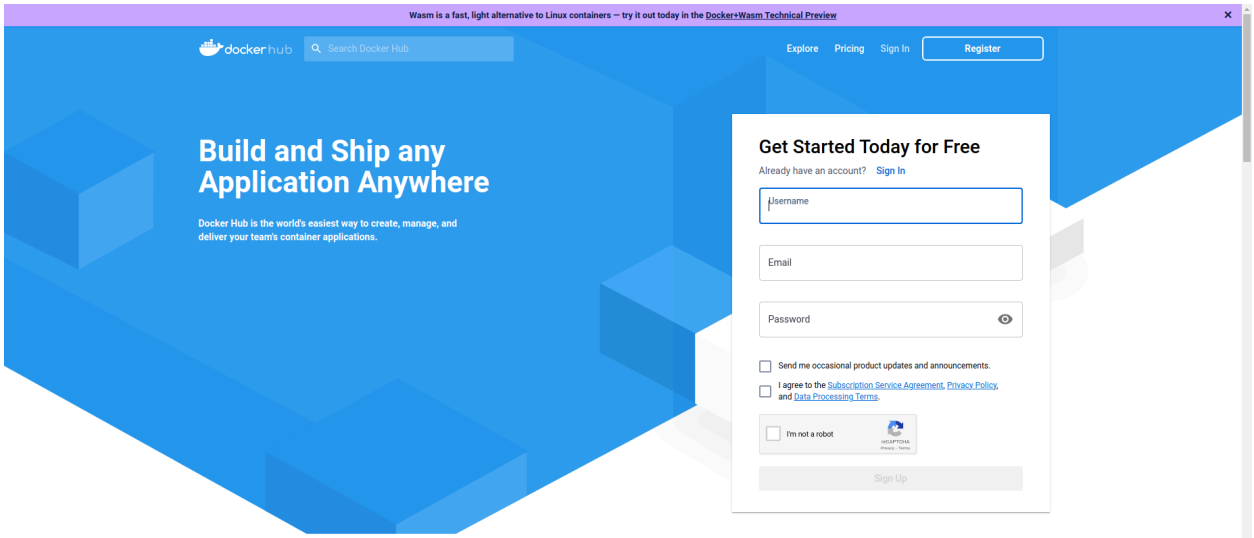
By the end of this lab exercise, you should be able to:

- Discuss Docker's standard image format
- Test and build Docker images manually
- Write Dockerfiles
- Understand the automated, iterative Docker image process
- Add the Docker packaging stage to the Jenkins pipeline
- Create per-stage agent configurations in Jenkinsfile

Registering with Docker Hub

As you prepare to work with the registry, it's important to have your own account. This account will enable you to build and push images to the registry. For the purpose of this tutorial, we'll be using a hosted registry called Docker Hub.

If you do not already have an account, visit the following link: https://hub.docker.com/ and sign up using your email.



Docker Hub is the world's largest

Check your email inbox and check the activation email sent by Docker.

After clicking on the activation link, you will be redirected to a login page. Enter your credentials and log in.

You will be taken to the Docker Hub main page. The registration process is complete and you have an account with Docker Hub.

Test Building Docker Image for the `worker` Application

Before you start building automated images, you will manually create a Docker image. You have already used the pre-built image from the registry in the last section. In this subsection, you will create an image with the **`worker`** application installed. Since **`worker`** a Java-based application that needs Maven to build, you will base your work on Maven's existing official image.

Enter the `example-voting-app/worker` directory.

Create a container named **`build`** with the **`maven:3.9.8-sapmachine-21`** image:

```
docker run -idt --name build maven:3.9.8-sapmachine-21 sh
```

Copy the source code. You must be inside the `example-voting-app/worker` directory for this to work:

```
docker container cp . build:/app
```

Connect to the container to compile and package the code:

```
docker exec -it build sh
```

```
cd app
```

```
mvn package
```

Verify the `.jar` file has been built:

```
ls target/
```

Run the `.jar` file with the following **java** command:

```
java -jar target/worker-jar-with-dependencies.jar
```

Sample output:

```
Waiting for redis
Waiting for redis
Waiting for redis
Waiting for redis
Waiting for redis
Waiting for redis
ctrl+c
```

*Use `Ctrl+c` to exit.

The above is the expected output. The `worker` app is waiting for `redis`.

Move the artifact:

```
mv target/worker-jar-with-dependencies.jar /run/worker.jar
```

Remove the source code:

```
rm -rf /app/*
```

Exit the container shell to return to your machine's shell:

```
exit
```

Commit the container to an image.

```
docker container commit build <xxxxx>/worker:v1
```

List your containers:

```
docker ps
```

Look for the container named `build` and take note of the container **ID**.

Commit the container into an image.

***NOTE**: Be sure to replace **<xxxxx>** with your own Docker Hub Account ID, that is your username.*

Test before pushing by launching the container with the packaged app:

```
docker run --rm -it <xxxxx>/worker:v1 java -jar /run/worker.jar
```

```
..
```

```
..
```

```
..
```

*Use **Ctrl + c** to exit.

Push the image to the registry.

***NOTE**: Before you push the image, you need to be logged in to the registry, with the Docker Hub ID created earlier.*

Login using the following command:

```
docker login
```

To push the image, first list it:

```
docker image ls
```

Sample output:

```
REPOSITORY         TAG    IMAGE ID       CREATED          SIZE
eeganlf/worker     v2     90cbeb6539df   18 minutes ago   194MB
eeganlf/worker     v1     c0199f782489   34 minutes ago   189MB
```

To push the image, use:

```
docker push <xxxxx>/worker:v1
```

Automated Image Build with Dockerfile

Now, let's build the same image, this time using a Dockerfile.

To do this, create a file and name it **Dockerfile** in the root of the source code for the **worker** app. It should have the path **example-voting-app/worker/Dockerfile**:

```
FROM maven:3.9.8-sapmachine-21
WORKDIR /app
```

```
COPY . .
RUN mvn package && \
    mv target/worker-jar-with-dependencies.jar /run/worker.jar && rm -rf /app/*
CMD ["java", "-jar", "/run/worker.jar"]
```

Let's build the image. Make sure you are in the `example-voting-app/worker` directory:

```
docker image build -t <xxxxx>/worker:v2 .
```

```
docker image ls
```

Try building again:

```
docker image build -t <xxxxx>/worker:v2 .
```

This time it runs much faster because Docker uses the cache.

Test the image using:

```
docker container run --rm -it <xxxxx>/worker:v2
```

You will see "waiting for redis" repeating in the console if it works.

*Use **`Ctrl + c`** to exit.

Tag the image as **`latest`**:

```
docker image tag <xxxxx>/worker:v2 <xxxxx>/worker:latest
```

```
docker image ls
```

Finally, publish images to the registry:

```
docker image push <xxxxx>/worker:latest
```

```
docker image push <xxxxx>/worker:v2
```

You must commit the Dockerfile into your Git repo before you can automate this process with Jenkins:

```
git add worker/Dockerfile
```

```
git commit -am "adding Dockerfile for worker"
```

```
git push origin feature/dockerfiles
```

Adding Docker Build and Publish Stages to Jenkinsfile

To have Jenkins build and publish a Docker image, you must add a pipeline script block. Copy and paste the following code inside the stages section between the **`package`** and **`post`** stages

of your `worker/Jenkinsfile`:

```
 stage('docker-package'){
     agent any
     steps{
       echo 'Packaging worker app with docker'
       script{
         docker.withRegistry('https://index.docker.io/v1/',
'dockerlogin') {  def workerImage =
docker.build("xxxx/worker:v${env.BUILD_ID}", "./worker")
             workerImage.push()
             workerImage.push("latest")
         }
       }
     }

}
```

The entire `worker/Jenkinsfile` pipeline should appear as follows, BUT notice the red text which should be replaced with your Docker Hub ID:

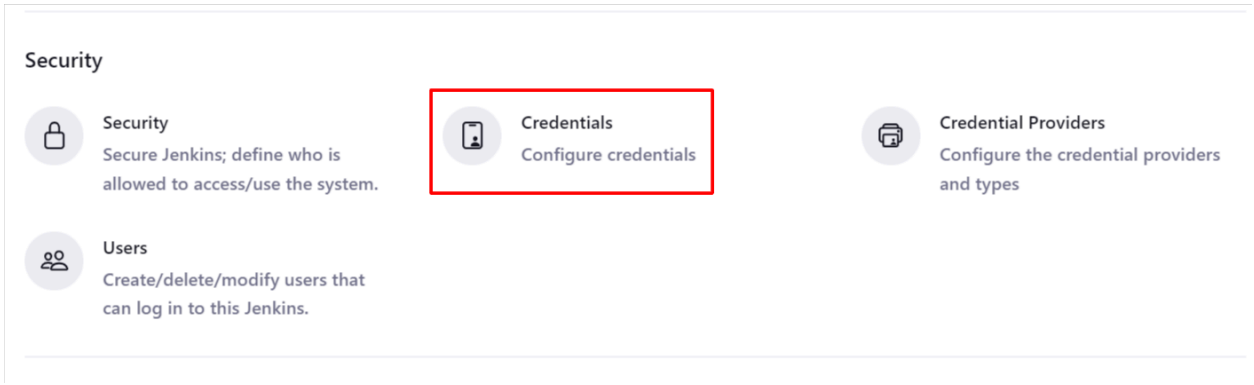
```
pipeline{

    agent{
      docker{
        image 'maven:3.9.8-sapmachine-21'
        args '-v $HOME/.m2:/root/.m2'
      }
    }

    stages{
        stage('build'){
            steps{
                echo 'building worker app'
                dir('worker'){
                  sh 'mvn compile'
                }
            }
        }
        stage('test'){
            steps{
                echo 'running unit tests on worker app'
                dir('worker'){
                  sh 'mvn clean test'
                }
            }
```

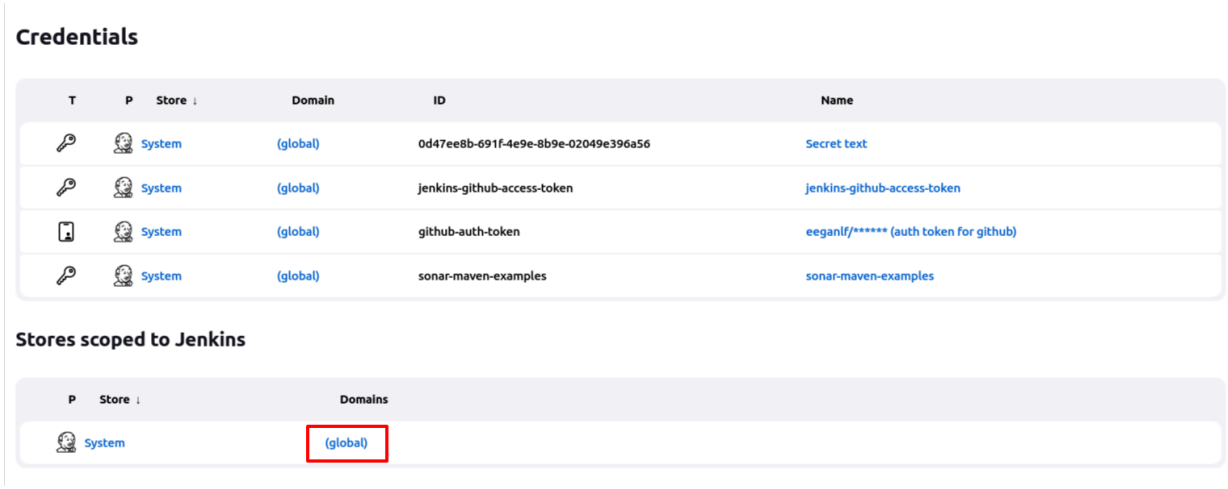
```
        }
        stage('package'){
            steps{
                echo 'packaging worker app into a jar file'
                dir('worker'){
                  sh 'mvn package -DskipTests'
                  archiveArtifacts artifacts: '**/target/*.jar',
fingerprint:  true
                }
            }
        }
        stage('docker-package'){
            agent any
            steps{
              echo 'Packaging worker app with docker'
              script{
                docker.withRegistry('https://index.docker.io/v1/',
'dockerlogin') {
                    def workerImage = docker.build("xxxxx/worker:v$
{env.BUILD_ID}", "./worker")
                    workerImage.push()
                    workerImage.push("latest")
                }
              }
            }
        }
    }

    post{
        always{
            echo 'the job is complete'
        }

    }

}
```

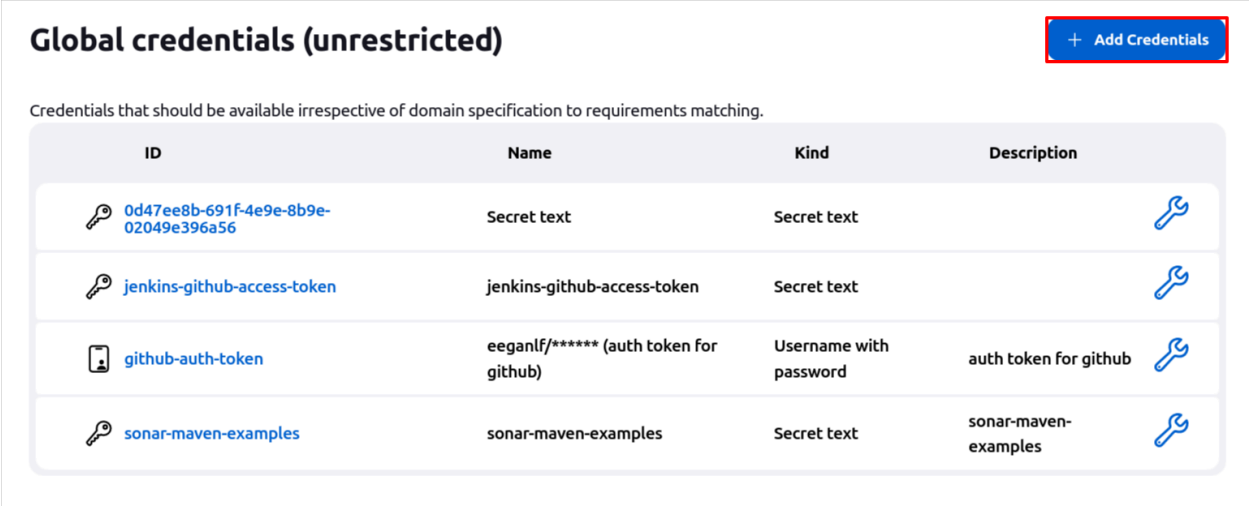
Adding Docker Hub Credentials

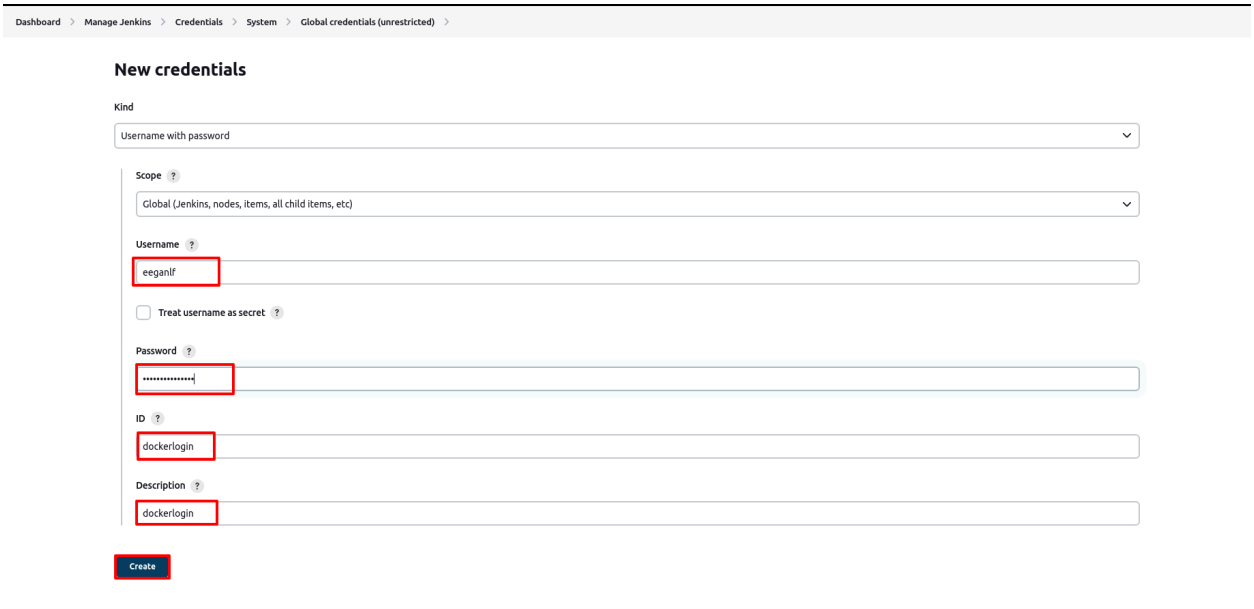
Add the username/password credentials to Jenkins with name **`dockerlogin`**. To do so, browse to **Jenkins Dashboard > Manage Jenkins > Credentials > Jenkins > Global Credentials > Add Credentials > Username and password**. Ensure you add the Docker Hub login and password with the ID as **`dockerlogin`**.

Reference the screenshots below to follow along.









Commit the changes you have made to the Jenkinsfile so that a new pipeline run is triggered. You will see the pipeline fail with an error similar to the one in the screenshot below.

```
$ docker exec --env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --
env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --
env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --
env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --
env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --env ******** --
env ******** --env ******** 30fdaceaf998f05ff55e943dc14873b7eca2f9f72c7018f6753627274a28edbe docker login
-u eeganlf -p ******** https://index.docker.io/v1/
OCI runtime exec failed: exec failed: unable to start container process: exec: "docker": executable file
not found in $PATH: unknown
```

In order to fix this error, you will have to add *Per Stage Agent* configurations.

Jenkinsfile Per Stage Agent Configurations

The following code contains the complete Jenkinsfile along with:

- Per Stage Agent configuration
- Conditional execution of the Docker **`package`** stage on the master
- Publishing the image on Docker Hub with the branch name as the tag

```
pipeline {

  agent none

  stages{
      stage("build"){
        when{
            changeset "**/worker/**"
          }

        agent{
          docker{
            image 'maven:3.9.8-sapmachine-21'
            args '-v $HOME/.m2:/root/.m2'
          }
        }

        steps{
          echo 'Compiling worker app..'
          dir('worker'){
            sh 'mvn compile'
          }
        }
      }
      stage("test"){
        when{
          changeset "**/worker/**"
        }
        agent{
          docker{
            image 'maven:3.9.8-sapmachine-21'
            args '-v $HOME/.m2:/root/.m2'
          }
        }
        steps{
          echo 'Running Unit Tests on worker app..'
          dir('worker'){
```

```
            sh 'mvn clean test'
           }

          }

      }
      stage("package"){
        when{
          branch 'master'
          changeset "**/worker/**"
        }
        agent{
          docker{
            image 'maven:3.9.8-sapmachine-21'
            args '-v $HOME/.m2:/root/.m2'
          }
        }
        steps{
          echo 'Packaging worker app'
          dir('worker'){
            sh 'mvn package -DskipTests'
            archiveArtifacts artifacts: '**/target/*.jar',
fingerprint: true
          }
        }
      }

      stage('docker-package'){
          agent any
          when{
            changeset "**/worker/**"
            branch 'master'
          }
          steps{
            echo 'Packaging worker app with docker'
            script{
              docker.withRegistry('https://index.docker.io/v1/',
'dockerlogin') {
                  def workerImage =
docker.build("xxxxx/worker:v${env.BUILD_ID}", "./worker")
                  workerImage.push()
                  workerImage.push("${env.BRANCH_NAME}")
                  workerImage.push("latest")
              }
            }
          }
```

```
        }
    }

    post{
      always{
          echo 'Building multibranch pipeline for worker is completed..'
      }
    }
}
```

You can access the **`worker/Jenkinsfile`** with the stage agents as well as conditional execution code here.

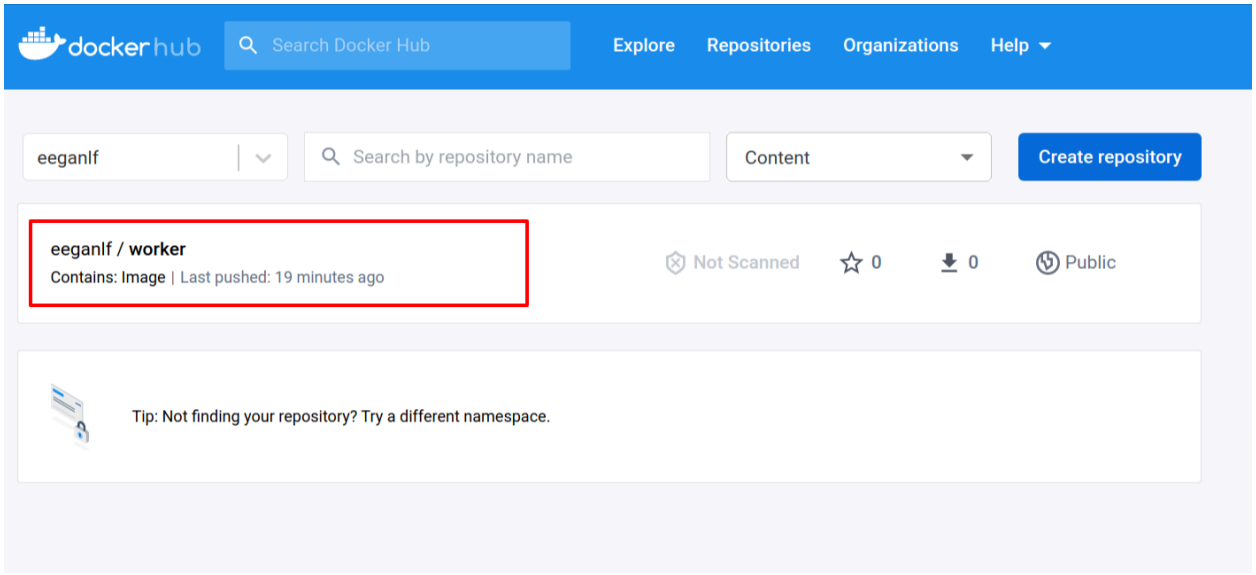
Once you edit your Jenkinsfile to this effect, commit the changes:

```
git commit -am "per stage agents, conditional execution"
```

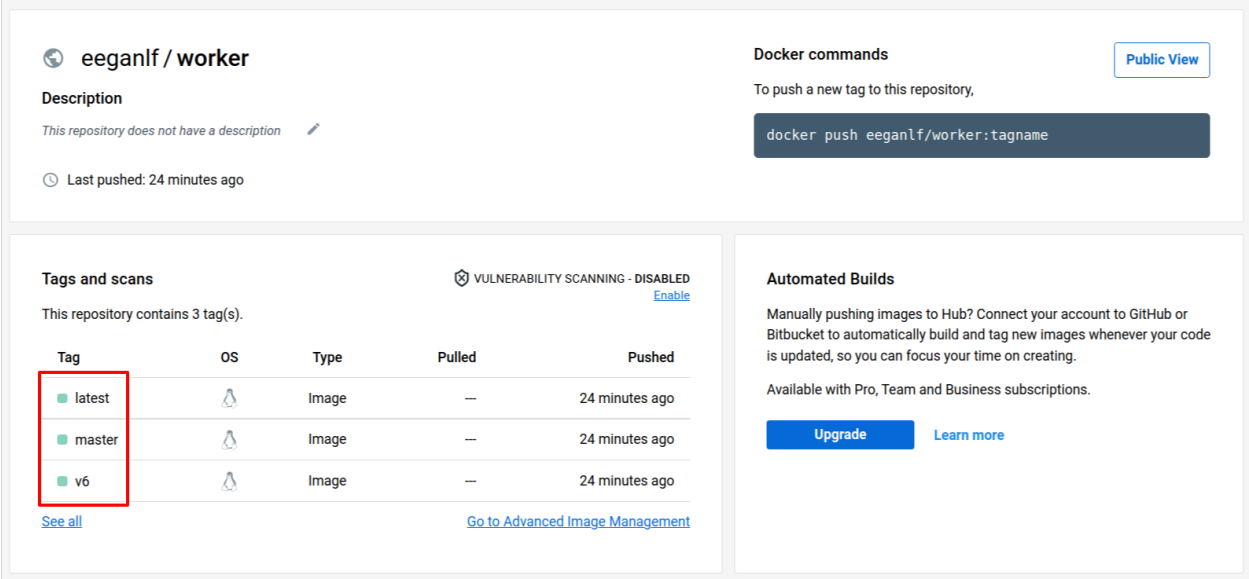
```
git push origin feature/dockerfiles
```

Merge the code into the master via a pull request. Remember not to delete the branch yet, as you will iterate the Jenkinsfile for **`vote`** and **`result`** applications with similar configurations.

Head over to the Docker Hub repository to validate that Jenkins has built and published images.



Click on the image.



Exercise: Vote and Result Application Dockerfiles

Follow the same process for **`vote`** and **`result`** applications:

- Check if Dockerfiles exist for **`vote`** and **`result`** applications. If not, create and check into the Git repository.
- Update Jenkinsfiles for **`vote`** and **`result`** applications with Docker Build and Publish stages.
- Make sure you refactor all Jenkinsfiles with Per Stage Docker Agent configurations.
- Validate the pipeline runs and images are visible on Docker Hub.

Result application - inside **`example-vote-app/result`**

The manual image sans Dockerfile creation process for the **`result`** application is as follows:

```
docker container run -idt --name nodebuild -p 80:80 node:22.4.0-slim

docker cp . nodebuild:/app  -this copies everything in . into
nodebuild container in the /app dir

docker exec -it nodebuild sh

which node
```

`which npm`

`cd app`

`npm install  -this will install modules from package.json`

`npm audit fix  -this will fix known vulnerabilities in the modules installed by npm`

`npm ls  - lists all modules downloaded by npm`

`npm test - runs unit tests to verify your code is ok`

`npm start`

`waiting for db` - will be repeatedly displayed

`ctrl + c`

`exit`

`docker container commit nodebuild xxxxx/result:v1` - this will create an image and tag it.

`docker image history xxxxx/result:v1` - this will show a list of commands entered inside containers run with the image. These will help build a Dockerfile for the image to automate the creation of containers based on the image.

`docker image push xxxxx/result:v1`

The automated build, using Dockerfile, is as follows. Create the `result/Dockerfile` file with the following code:

```
FROM node:22.4.0-slim

# add curl for healthcheck
RUN apt-get update && \
    apt-get install -y --no-install-recommends curl tini && \
    rm -rf /var/lib/apt/lists/*

WORKDIR /usr/local/app

# have nodemon available for local dev use (file watching)
RUN npm install -g nodemon

COPY package*.json ./

RUN npm ci && \
 npm cache clean --force && \
 mv /usr/local/app/node_modules /node_modules
```

```
COPY . .

ENV PORT 80
EXPOSE 80

ENTRYPOINT ["/usr/bin/tini", "--"]
CMD ["node", "server.js"]
```

docker image build -t xxxxx/result:v2 . - DO NOT FORGET THE PERIOD because it tells Docker the path to the Dockerfile that will be used to build the image.

docker image tag xxxxx/result:v2 xxxxx/result:latest

docker image push xxxxx/result

Vote application - inside **example-vote-app/vote**

Create a **Dockerfile** inside the **vote/** directory with the following code:

```
# Define a base stage that uses the official python runtime base image
FROM python:3.11-slim AS base

# Add curl for healthcheck
RUN apt-get update && \
    apt-get install -y --no-install-recommends curl && \
    rm -rf /var/lib/apt/lists/*

# Set the application directory
WORKDIR /usr/local/app

# Install our requirements.txt
COPY requirements.txt ./requirements.txt
RUN pip install --no-cache-dir -r requirements.txt

# Define a stage specifically for development, where it'll watch for
# filesystem changes
FROM base AS dev
RUN pip install watchdog
ENV FLASK_ENV=development
CMD ["python", "app.py"]

# Define the final stage that will bundle the application for
production
FROM base AS final

# Copy our code from the current folder to the working directory
inside the container
```

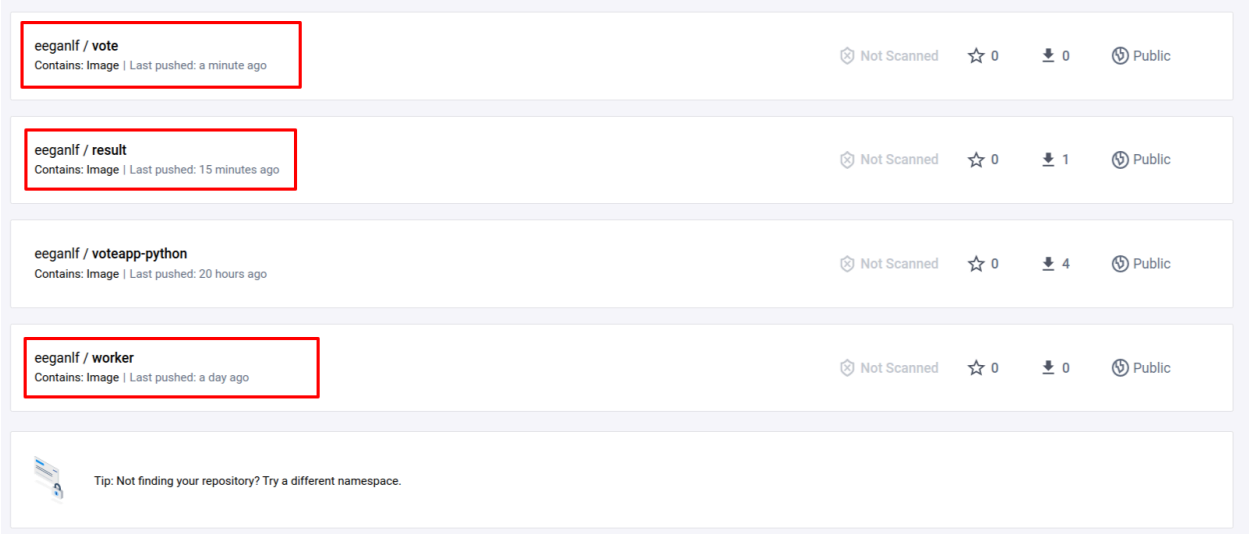
```
COPY . .

# Make port 80 available for links and/or publish
EXPOSE 80

# Define our command to be run when launching the container
CMD ["gunicorn", "app:app", "-b", "0.0.0.0:80", "--log-file", "-",
"--access-logfile", "-", "--workers", "4", "--keep-alive", "0"]
```

`docker image build -t xxxxx/vote:v1 .` -DO NOT FORGET THE PERIOD because it tells Docker the path to the Dockerfile that will be used to build the image.

`docker image tag xxxxx/vote:v1 xxxxx/vote:latest`

`docker image push xxxxx/vote`

You should now see your images on your Docker Hub repository page with any other images you may have pushed in the past:



These images will be required for the next lab.

Lab 8. Deploy to Dev with Docker Compose

By the end of this lab exercise, you should be able to:

- Explain how Docker Compose can launch a monitoring stack
- Add services to Docker Compose
- Create a consolidated Jenkins pipeline
- Start deploying to an integrated dev environment with Docker Compose

Before you begin, create a new branch and switch to it:

```
git checkout -b feature/monopipe
```

Also, enter the `devops-repo/setup` directory and shut Jenkins down while we explore the next steps:

```
cd devops-repo/setup
```

```
docker compose down
```

We will restart Jenkins after exploring the example voting application. If we do not shut Jenkins down, there will be port conflicts.

Create a Simple Docker Compose Spec

***NOTE**: Be sure to replace **xxxxx** with your Docker Hub ID.*

```
cd example-voting-app
```

Create the `docker-compose.yaml` with the following contents.

file: example-voting-app/docker-compose.yaml

```
services:
  vote:
    image: xxxxx/vote:latest
    ports:
      - 5000:80

  result:
    image: xxxxx/result:latest
    ports:
      - 5001:80

  worker:
    image: xxxxx/worker:latest
```

You can access the file here.

***NOTE**: Be sure to replace **xxxxx** with your Docker Hub ID.*

Launch the stack with:

```
docker compose up -d
```

```
docker compose ps
```

At this time, if you try submitting the vote from the UI, you will see an error. That is because you have not provisioned the backend service, i.e. **redis**.

Add **redis** along with **db** in **docker-compose.yaml**:

file: example-voting-app/docker-compose.yaml

```
services:
  vote:
    image: xxxxx/vote:latest
    ports:
      - 5000:80

  redis:
    image: redis:alpine

  db:
    image: postgres:15-alpine

  result:
    image: xxxxx/result:latest
    ports:
```

```
      - 5001:80

  worker:
    image: xxxxx/worker:latest
```

You can access this Docker Compose yaml file here.

***NOTE**: Be sure to replace **xxxxx** with your Docker Hub ID.*

Launch the new services using the same command as earlier:

```
docker compose up -d
```

```
docker compose ps
```

At this time, if you attempt to submit the vote using the UI, it should go through. This validates the service discovery (connecting **vote** with **redis**).

Add Networks and Volumes

To add networks and volumes to the example voting application, copy the following into your **example-voting-app/docker-compose.yaml**:

```
volumes:
  db-data:

networks:
  instavote:
    driver: bridge

services:
  vote:
    image: xxxxx/vote:latest
    ports:
      - 5000:80
    depends_on:
      - redis
    networks:
      - instavote

  redis:
    image: redis:alpine
    networks:
      - instavote

  db:
    image: postgres:15-alpine
```

```
    environment:
      POSTGRES_USER: "postgres"
      POSTGRES_PASSWORD: "postgres"
    volumes:
      - "db-data:/var/lib/postgresql/data"
      - "./healthchecks:/healthchecks"
    healthcheck:
      test: /healthchecks/postgres.sh
      interval: "5s"
    networks:
      - instavote

  result:
    image: xxxxx/result:latest
    ports:
      - 5001:80
    depends_on:
      - db
    networks:
      - instavote

  worker:
    image: xxxxx/worker:latest
    depends_on:
      - redis
      - db
    networks:
      - instavote
```

***NOTE**: Be sure to replace **xxxxx** with your Docker Hub ID.*

As usual, launch it again with **`docker compose`**:

```
docker compose up -d
```

```
docker compose ps
```

You can find the complete Docker Compose file here.

Additional Docker Compose Commands to Explore

This command will list containers and the images used to create them.

```
docker compose images
```

The following commands will list logs of running services. The first will list all the logs of all the services. The second command demonstrates that you can specify a service from the `docker-compose.yaml` as an option to only show the logs for that service, in this example **`worker`**:

```
docker compose logs
```

```
docker compose logs worker
```

The following command pulls an image associated with a service defined in a `docker-compose.yml` or `docker-stack.yml` file, but does not start containers based on those images.

```
docker compose pull
```

The following command will execute a command inside a service. The following example specifically runs the **`ps`** command inside the **`vote`** service:

```
docker compose exec vote ps
```

The following command stops running containers without removing them. They can be started again with **`docker compose start`**:

```
docker compose stop
```

The following command stops and removes containers and networks:

```
docker compose down
```

If you run **`docker compose logs`** after running **`docker compose down`**, nothing will be displayed because it removes everything. You can get started again with **`docker compose up -d`**.

Finishing Up

Push the changes you have made so far to the repository:

```
git add docker-compose.yaml
```

```
git commit -am "adding docker compose spec"
```

```
git push origin feature/monopipe
```

Integrate Docker Compose with Dockerfiles

So far, you have been using pre-baked images to deploy to development. You can also have Docker Compose build the images by calling the respective Dockerfiles. Below is the code which will allow you to do this. Replace **xxxxx** with your DockerHub user ID.

```
volumes:
  db-data:

networks:
  instavote:
    driver: bridge

services:
  vote:
    image: xxxxx/vote:latest
    build: ./vote
    ports:
      - 5000:80
    depends_on:
      - redis
    networks:
      - instavote

  redis:
    image: redis:alpine
    networks:
      - instavote

  db:
    image: postgres:15-alpine
    environment:
      POSTGRES_USER: "postgres"
      POSTGRES_PASSWORD: "postgres"
    volumes:
      - "db-data:/var/lib/postgresql/data"
      - "./healthchecks:/healthchecks"
    healthcheck:
      test: /healthchecks/postgres.sh
      interval: "5s"
    networks:
      - instavote

  result:
    image: xxxxx/result:latest
    build: ./result
```

```
    ports:
      - 5001:80
    depends_on:
      - db
    networks:
      - instavote

  worker:
    image: xxxxx/worker:latest
    build: ./worker
    depends_on:
      - redis
      - db
    networks:
      - instavote
```

You can access the Docker Compose spec with Dockerfile build integration here.

You can build and deploy using the following commands:

```
docker compose config
```

```
docker compose build
```

`docker compose build` (observe caching)

```
docker compose up -d
```

```
docker compose ps
```

Finally, be sure to run:

```
docker compose down
```

If you forget to do this, it will cause issues when you restart Jenkins and the DinD containers. Restart Jenkins and DinD by running the following from inside the `devops-repo/setup/` directory:

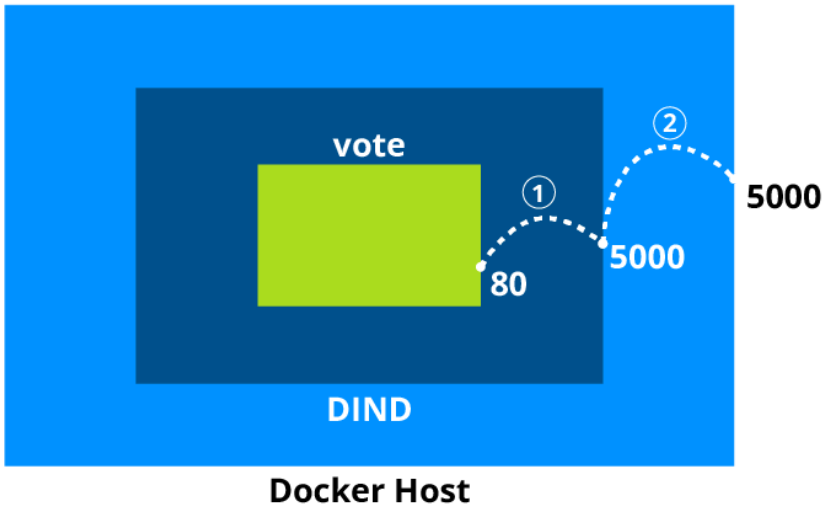
```
docker compose up -d
```

You are now ready to move on to the next section.

Add New Port Mapping

You will have to define an additional port mapping from inside `devops-repo/setup/docker-compose.yaml` and redeploy it. The following diagram depicts the two level port mappings:

1. example-vote-app/docker-compose.yaml



2. devops-repo/setup/docker-compose.yaml

Edit the **compose** spec used to set up Jenkins and DIND server by adding new port mappings. Be sure to remove any previous containers consuming these ports before you do so. Make sure the following is in `devops-repo/setup/docker-compose.yaml`:

```
docker:
  image: docker:dind
  ports:
    - 2376:2376
    - 5000:5000
    - 5001:5001
  environment:
    - DOCKER_TLS_CERTDIR=/certs
```

You can access the `docker-compose.yaml` file here.

After making this change, redeploy the setup using `docker compose up -d` from the setup directory. It will not disturb or recreate Jenkins, but it will relaunch the Docker DIND environment with new port mappings. Take care of any port conflicts that may exist while you bring up this environment.

Exercise: Create a Consolidated Pipeline for Instavote Stack

You have created one Jenkinsfile per application, matching **vote**, **worker**, and **result** apps. Consolidating all those stages and building one single pipeline for the **instavote** app is called

a **Mono Pipe**. As an exercise, use the following steps as a loose reference while attempting to complete this exercise on your own:

- Copy over **`worker/Jenkinsfile`** to the top level directory, i.e. **`example-voting-app/Jenkinsfile`.**
- Rename stages to identify with the application name. i.e. **`worker`**.
- Bring in just the stages from **`result/Jenkinsfile`** and **`vote/Jenkinsfile`**.
- Commit the changes to the repository branch created earlier, i.e. **`feature/monopipe`**.
- Create a new Multi Branch Pipeline job.

Once you validate the pipeline, add the “deploy to dev” stage.

Add “Deploy to Dev” with Docker Compose

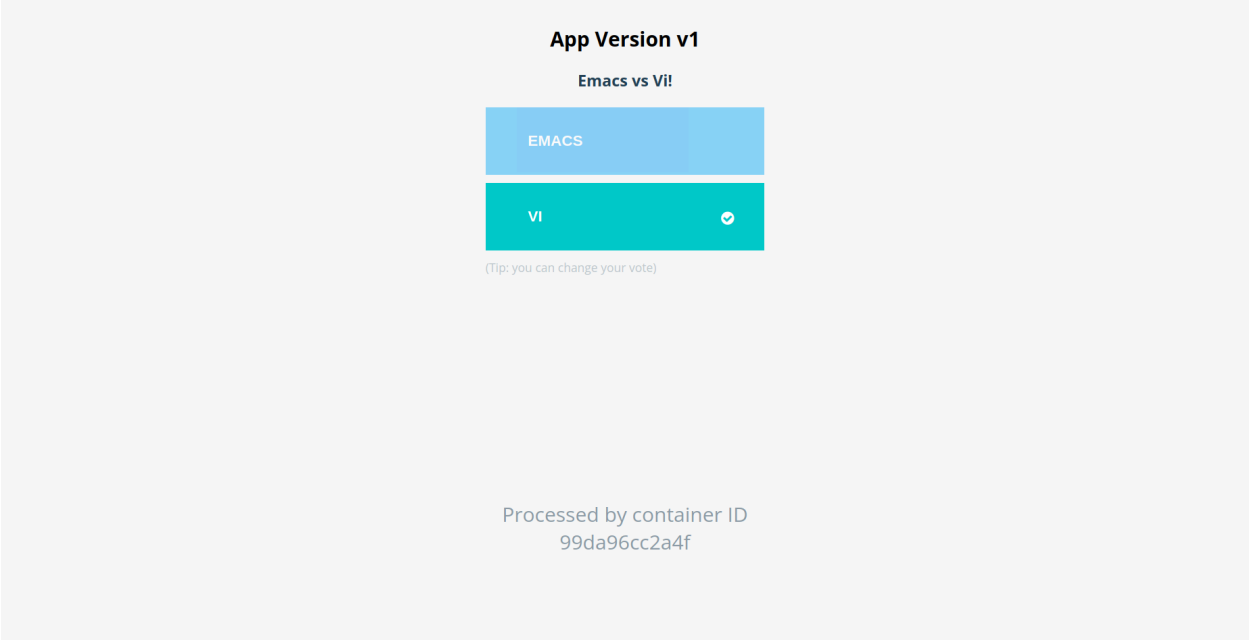
Add a “deploy to dev” stage to Jenkinsfile using the following stage snippet:

```
stage('deploy to dev'){
    agent any
    when{
      branch 'master'
    }
    steps{
      echo 'Deploy instavote app with docker compose'
      sh 'docker compose up -d'
    }
}
```

You can access the **“**deploy to dev” stage snippet here.

The entire Jenkinsfile for the Mono Pipe can be found here.

Be sure to push your changes to Github. After Jenkins runs the Mono Pipe job, you should be able to visit **`IPADDRESS:5000`**, for example **`localhost:5000`**, to see the vote application is up and running:



In this lab, we learned how to draft a `docker-compose.yaml` document and implemented a Mono Pipe with Jenkins. We also instructed Jenkins to automatically deploy our application. This concludes Lab 8.

Lab 9. Continuous Testing

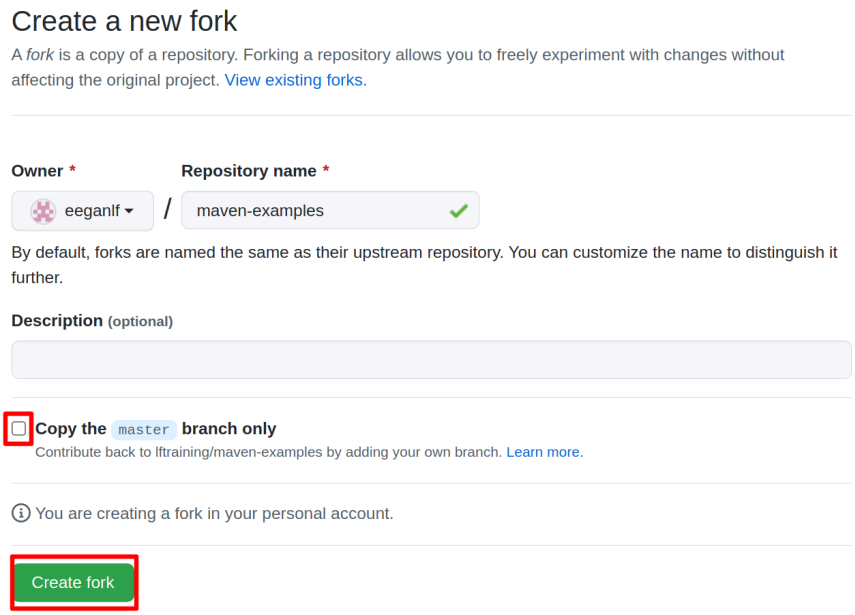
By the end of this lab exercise, you should be able to:

- Analyze code coverage with JaCoCo
- Improve the code coverage
- Set up SonarQube to automatically scan your repository
- Create a project gating system to automatically decide whether the code is safe to deploy
- Add integration and acceptance tests with Docker Compose
- Incorporate all of the steps into the Jenkins pipeline

Code Coverage with Jacoco

Create a new Jenkins project which will download the following sample repository and run unit tests with a Jacoco plugin for Java and display code coverage reports.

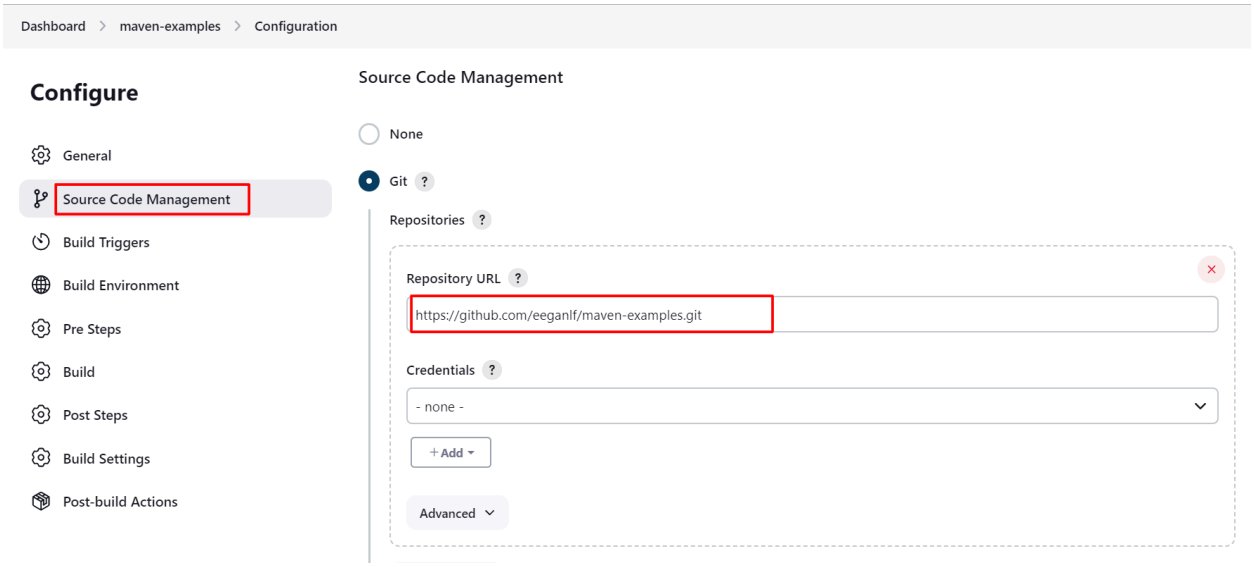
Fork the maven-examples repository to your GitHub account. Be sure to *uncheck* the **Copy the master branch only** option, as follows:



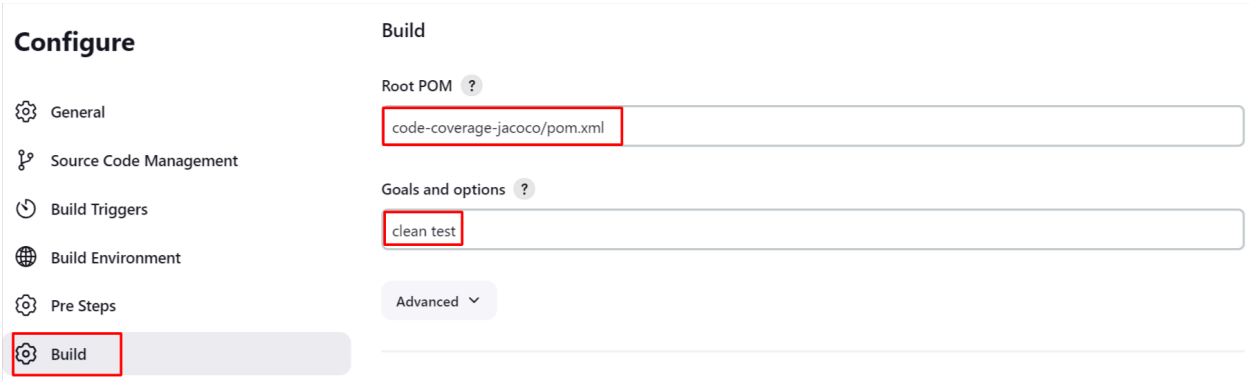
Install the **Coverage** Plugin for Jenkins.

Create a Maven project named **`maven-examples`**, provide the repository you forked as source, add Maven goals to run tests on it. Use “clean test” as the Maven goal.

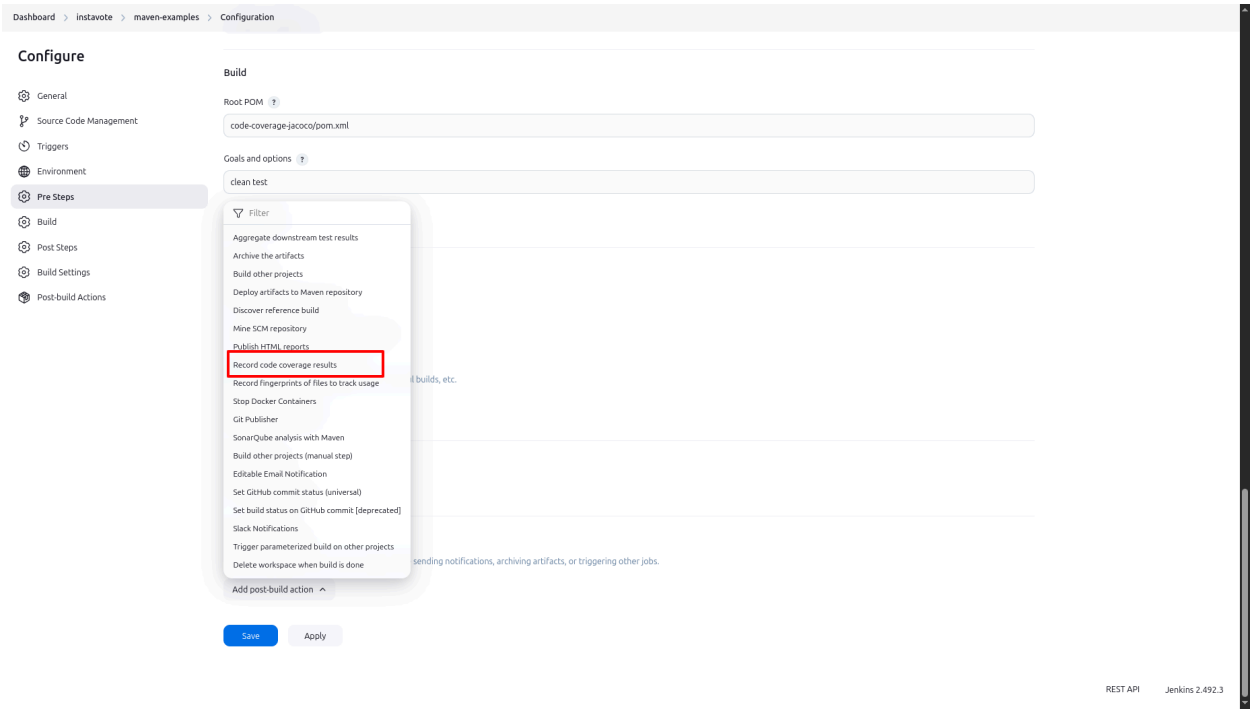
Under the **Source Code Management** section, select **Git** and paste the repository URL of the **`maven-examples`** repository that you forked.



Under the **Build** section, enter the path to the `pom.xml` as `code-coverage-jacoco/pom.xml`, and type **clean test** into the **Goals** text box.

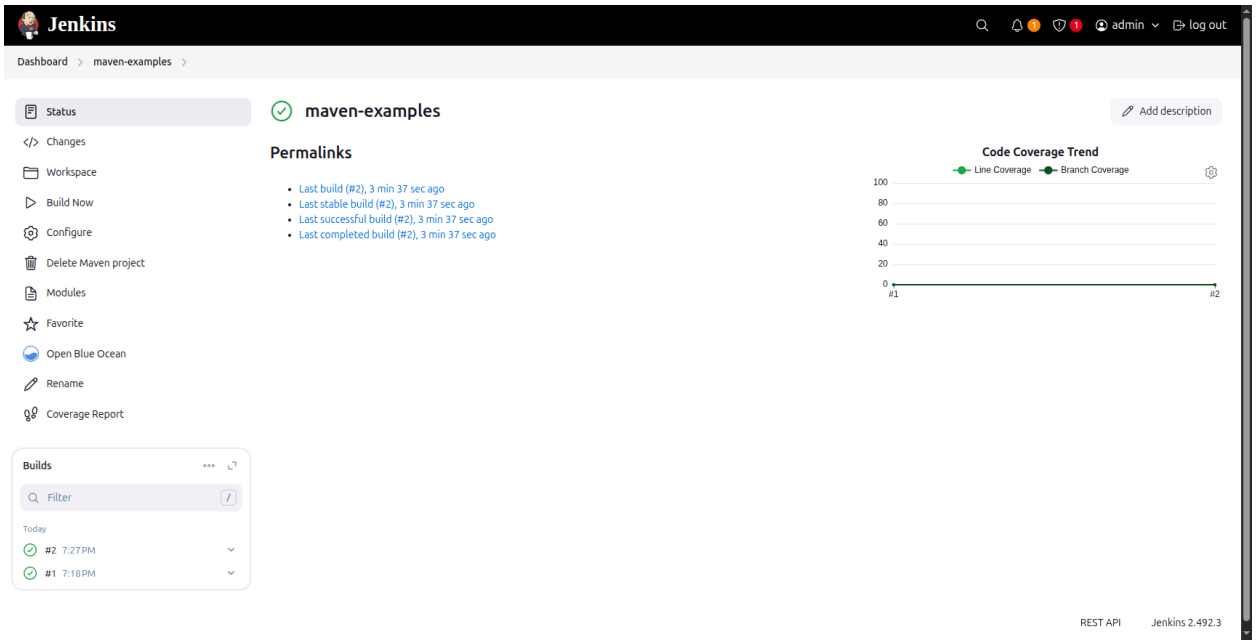


From post-build actions, choose **Record code coverage results**.



Select **JaCoCo Coverage Reports** as the **Coverage Parser** and **Save**.

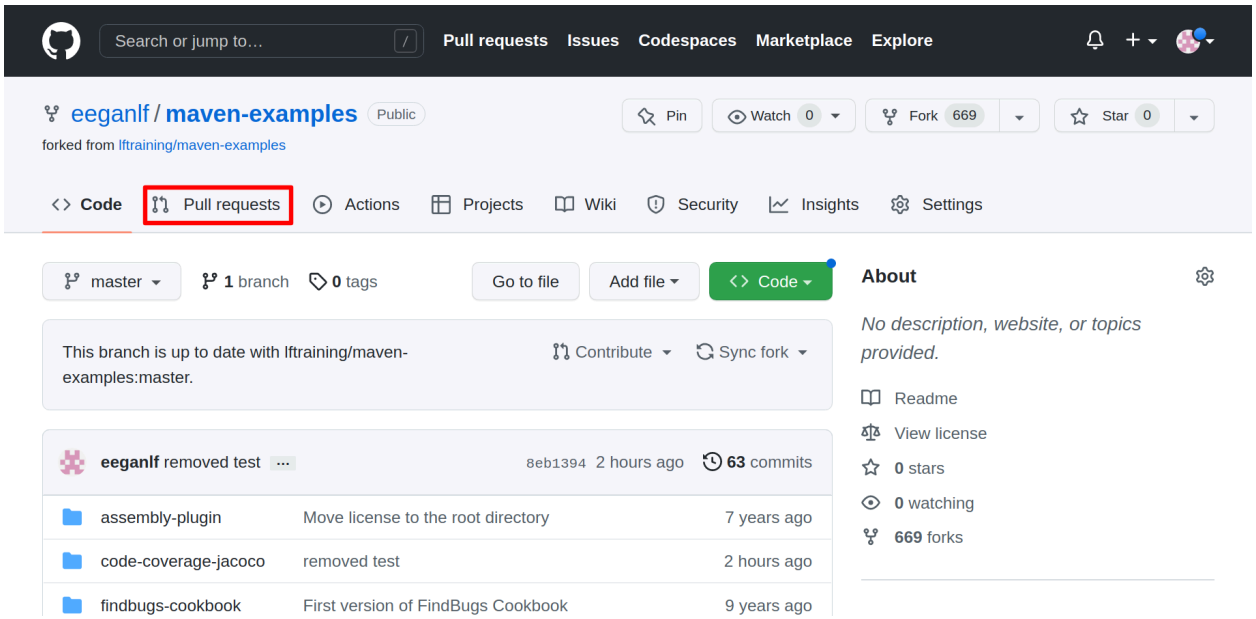
Build the project twice and refresh the page after the build is complete:



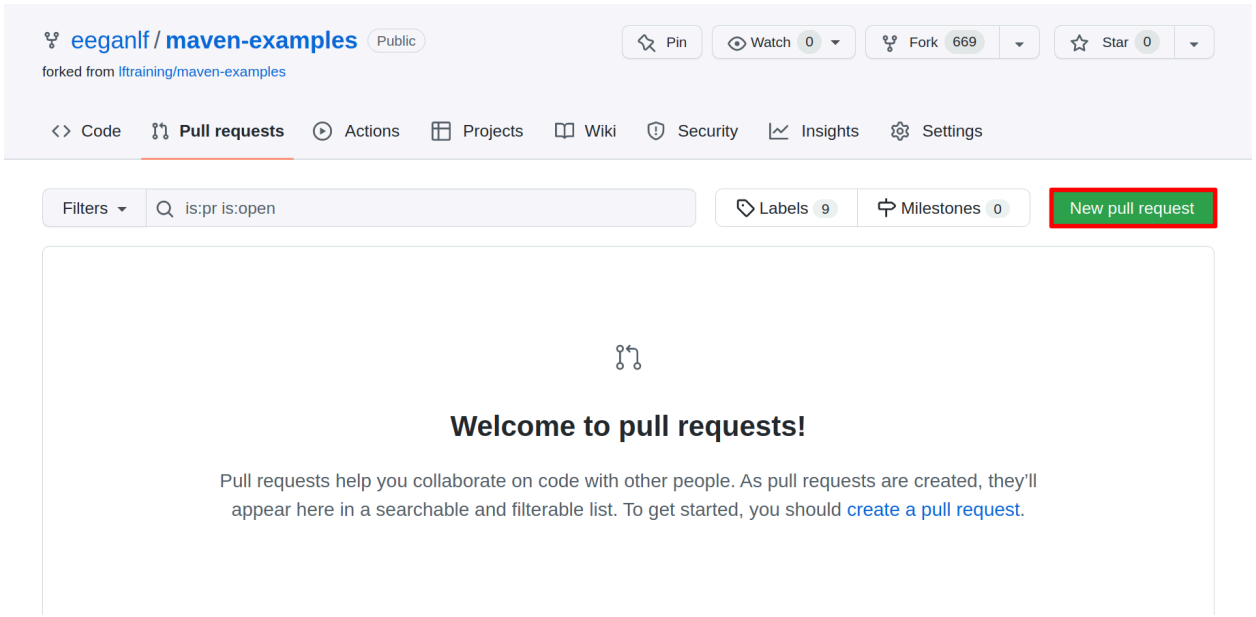
You should see a Code Coverage Trend between the two builds. It won't show much at the moment because you have only built the project once and there are no tests. You will add tests to the master branch next.

Create and merge a pull request from the `ut1` branch in your repository onto your `master` branch.

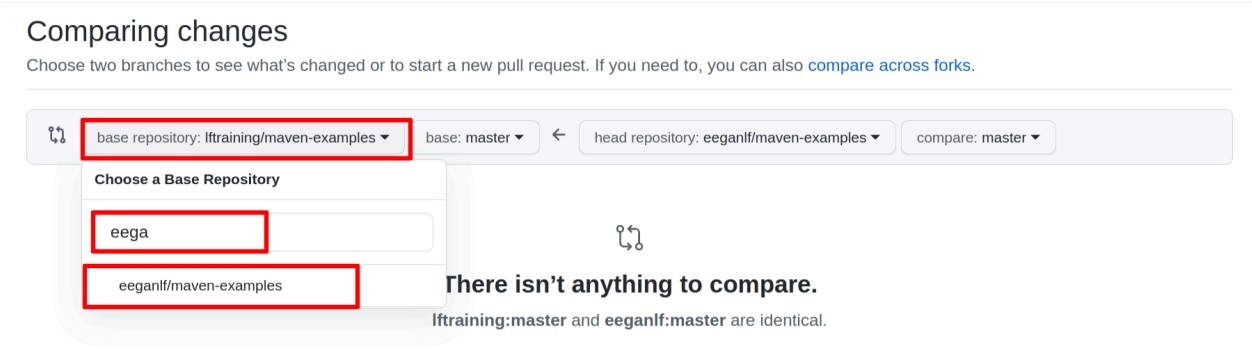
First, navigate to **Pull requests**:



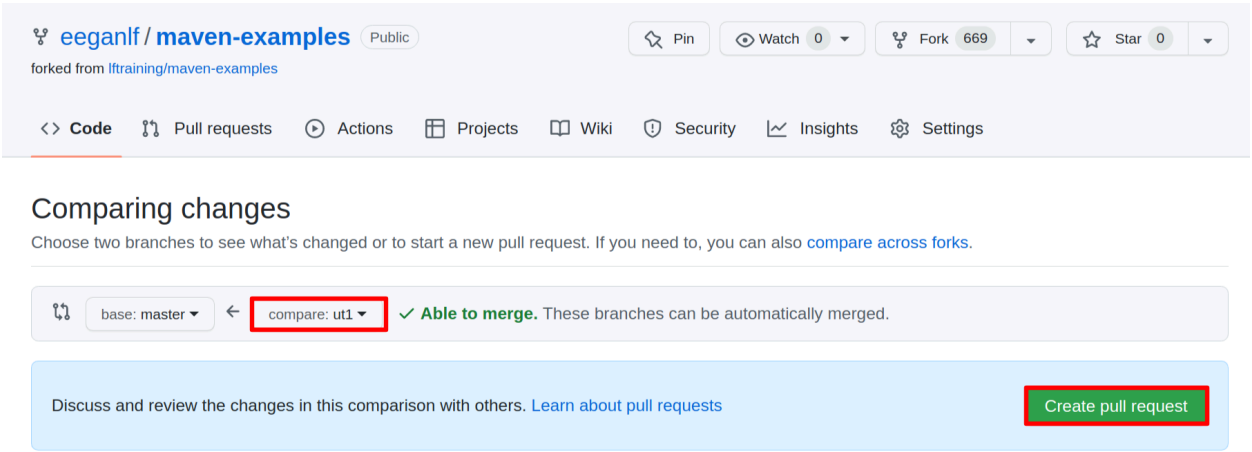
Click **New pull request**:



Click on the **base repository** dropdown and search for your GitHub username. When you find your repository, select it as the base repository:



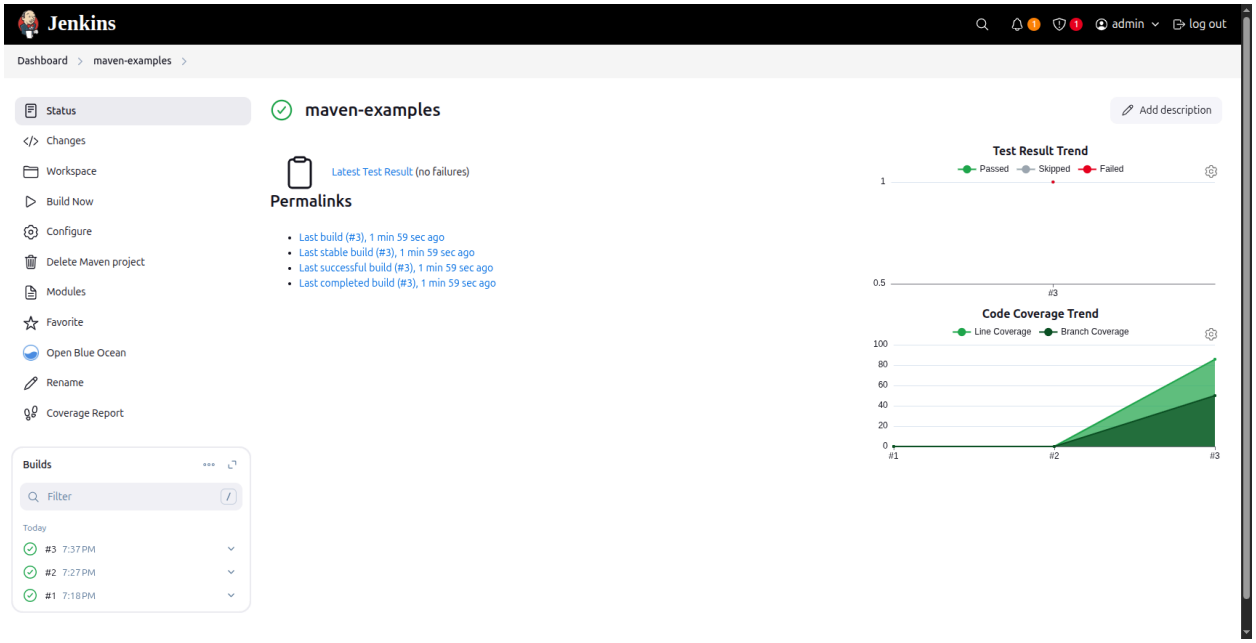
Select the `ut1` branch as the branch to **compare** and click **Create pull request**:



Approve the request as normal.

This will add pre-written tests to your master branch so that Jacoco will show some coverage in Jenkins.

Go back to the Maven project page you created earlier and build the project; refresh the page when the build is finished and you should see a code coverage report get published on the project page.



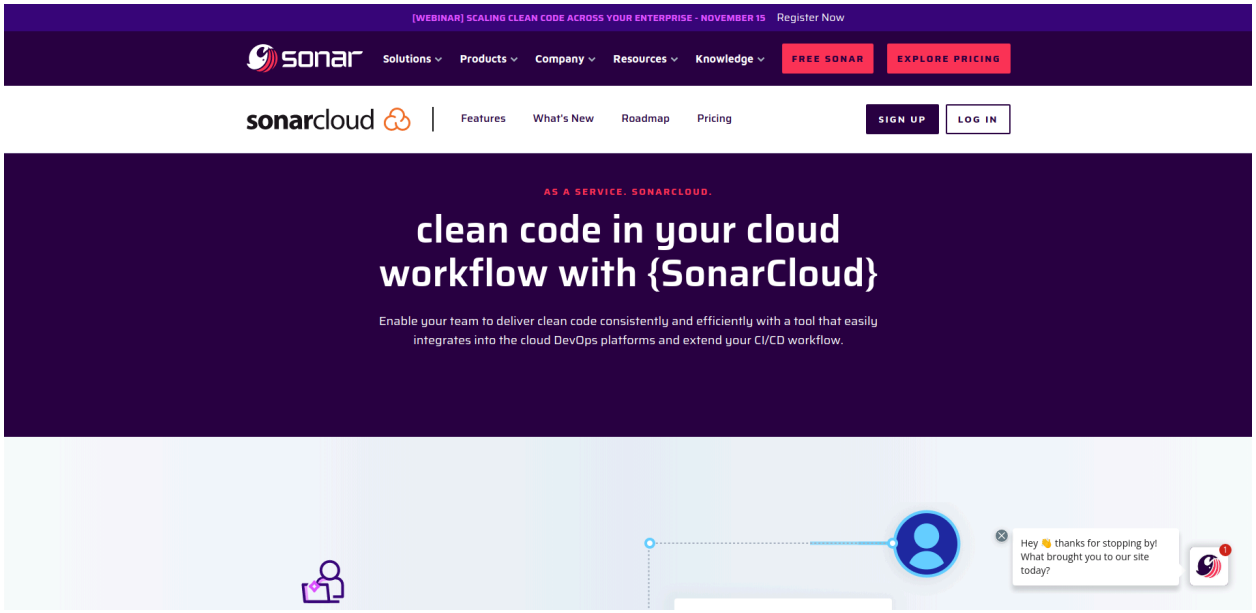
Adding Static Code Analysis with SonarQube

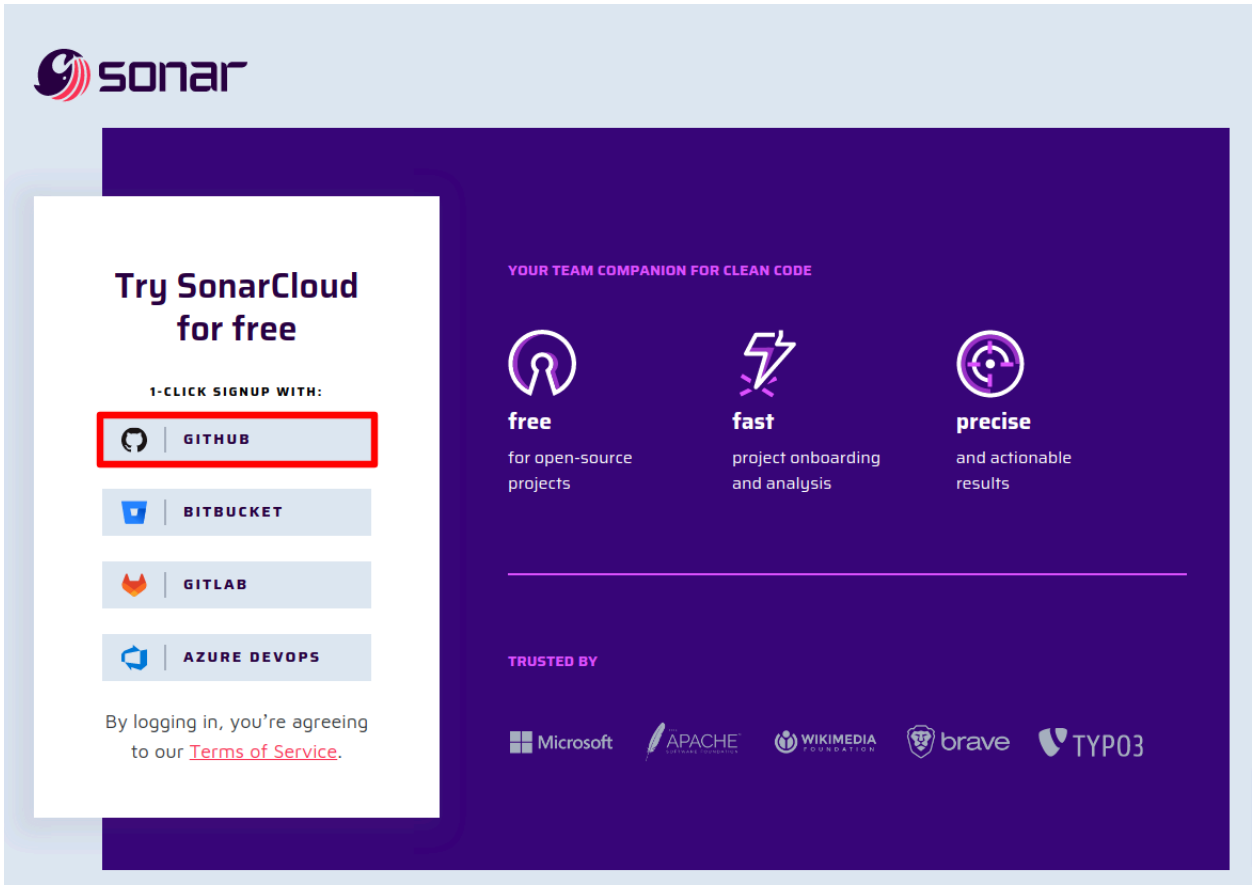
Steps:

- Set up Sonar Cloud.
- Install SonarQube Scanner plugin for Jenkins.
- Configure SonarQube Servers from Jenkins Systems Configuration.

Set Up Sonar Cloud as SonarQube Server

Head over to SonarCloud and sign up using your GitHub account.

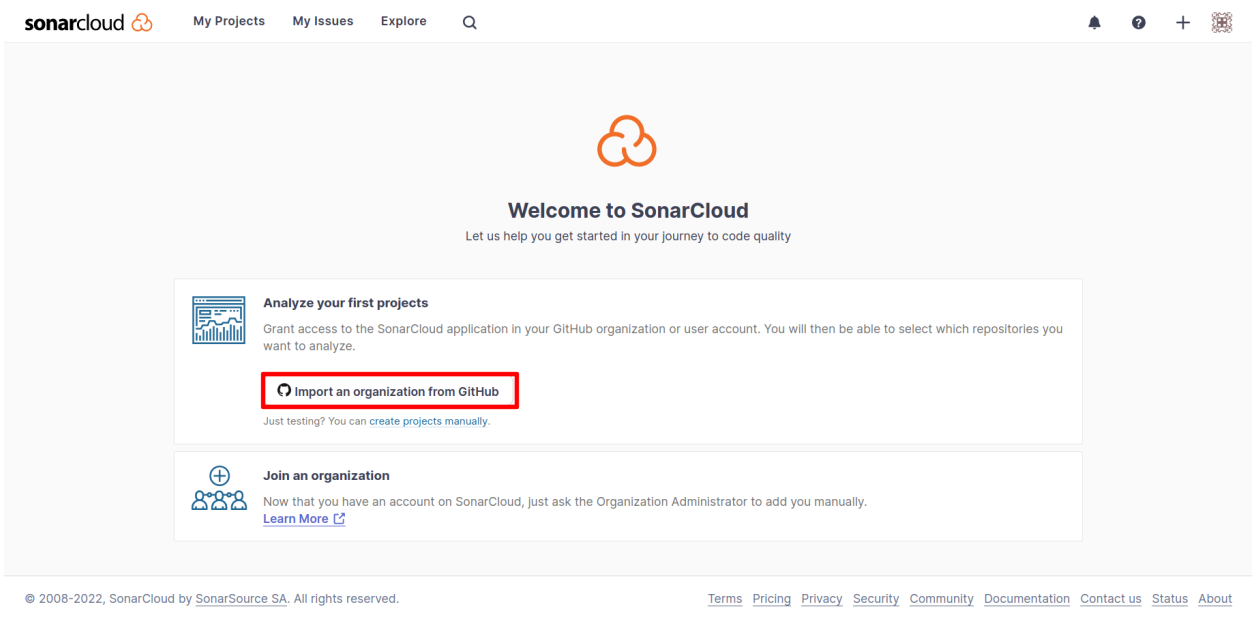




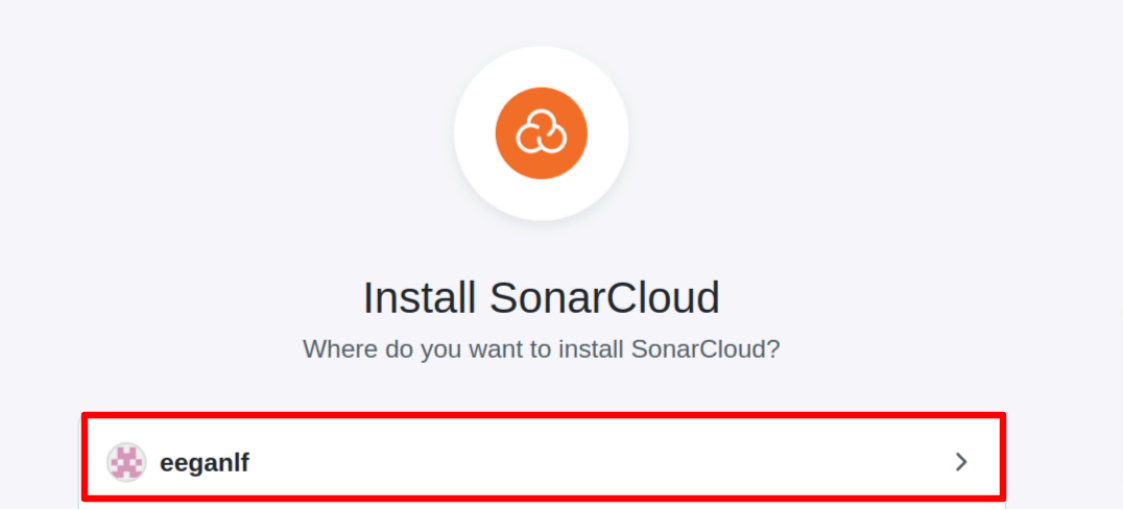
Ensure that you are logged into the GitHub account from the same browser in order to provide

authorization. Follow the prompts to authorize SonarCloud with GitHub.

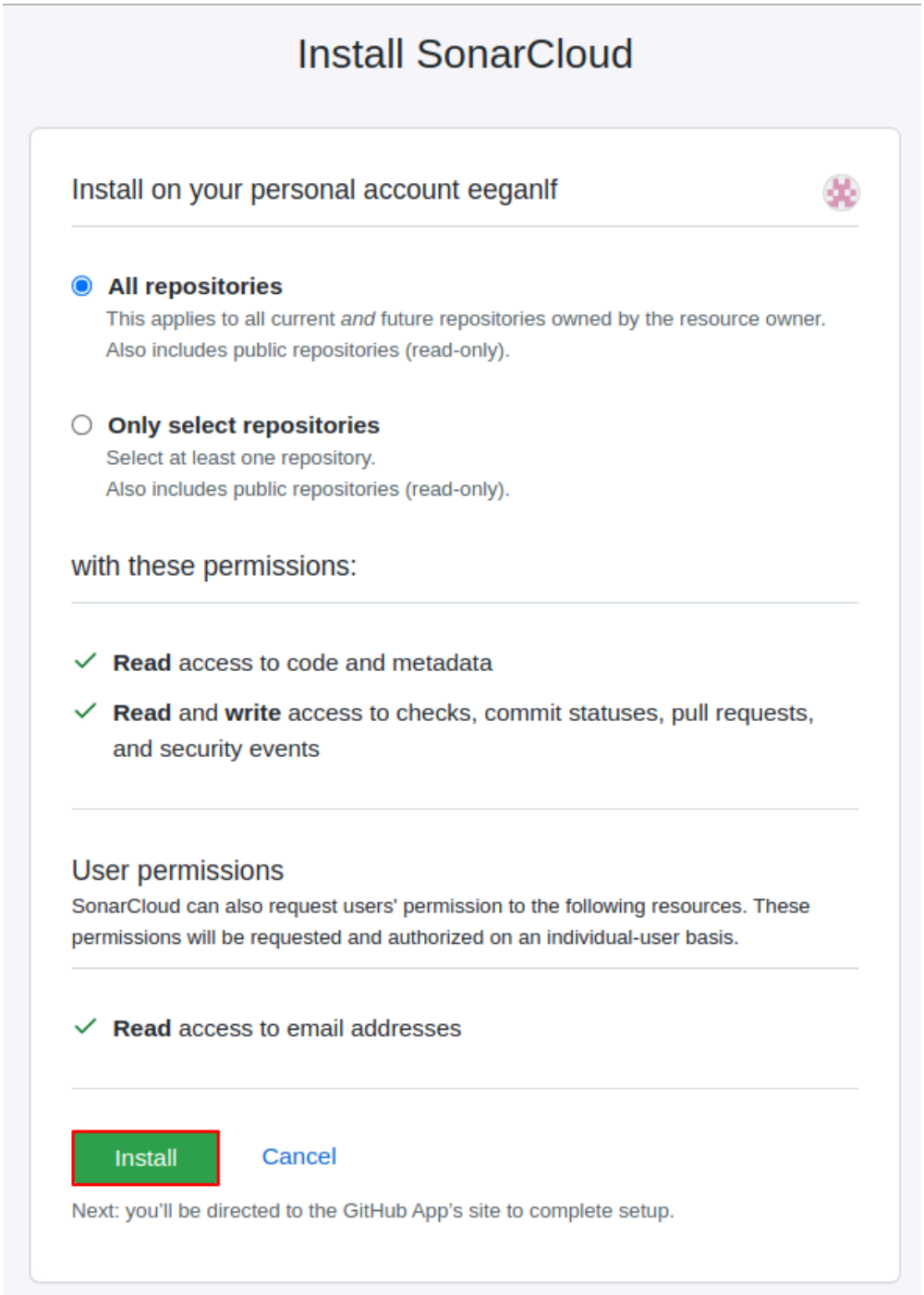
From the welcome page, click **Import an organization from GitHub.**



Choose your GitHub organization.



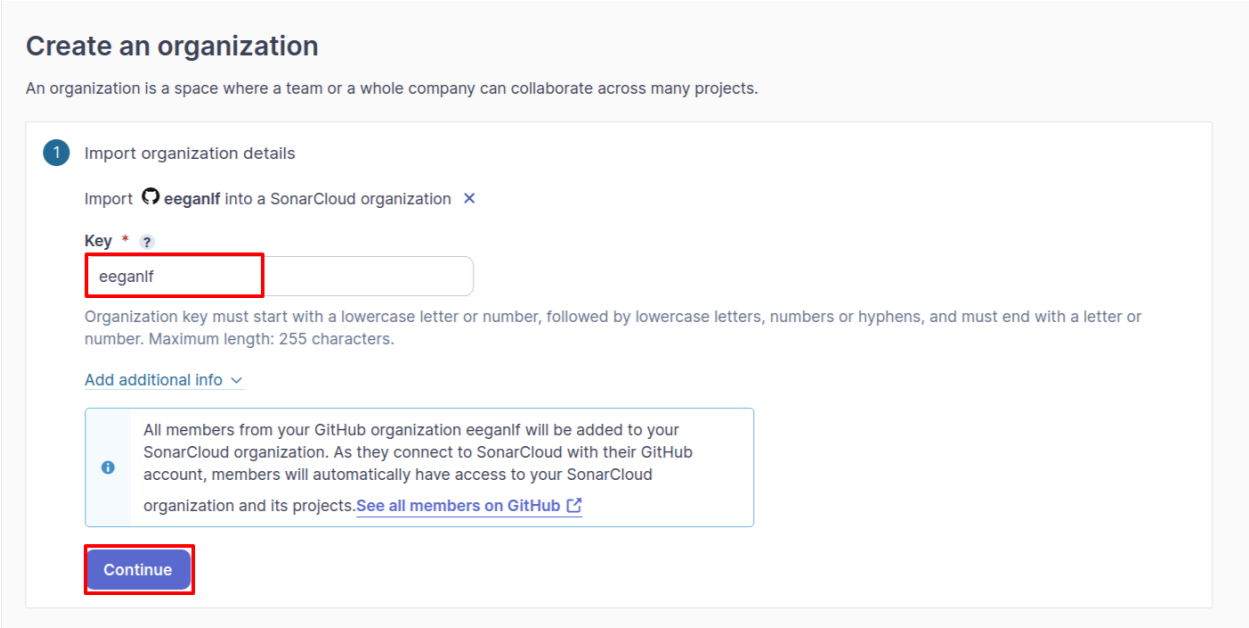
Provide access to all your repositories:



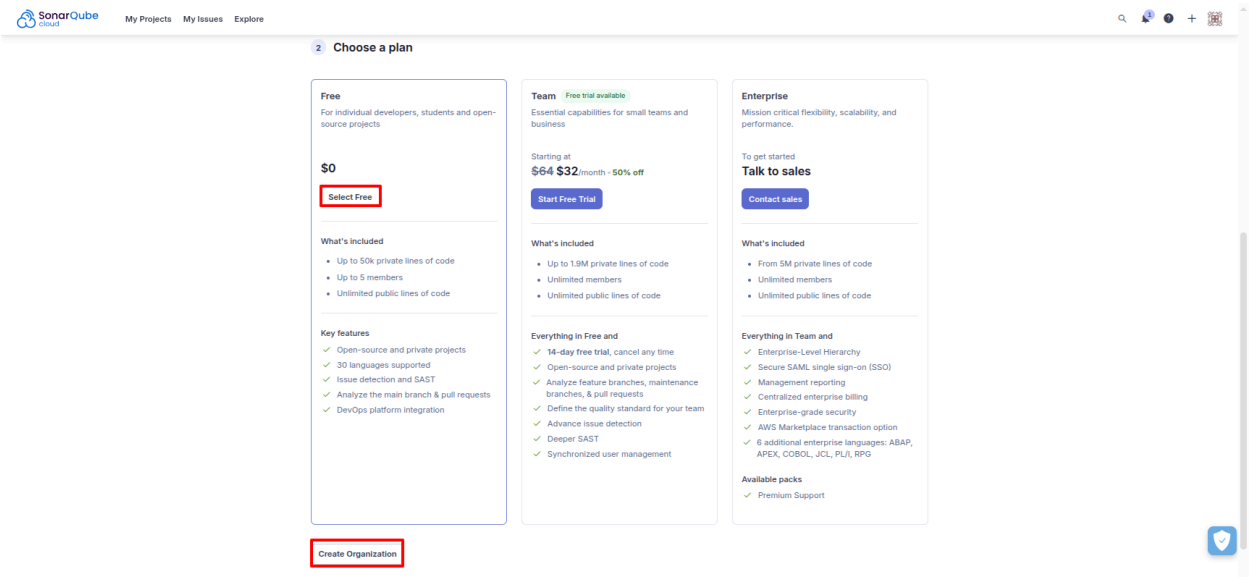
You will be redirected back to SonarCloud.

Provide an organization name to be created on SonarCloud. This is important, as you are going

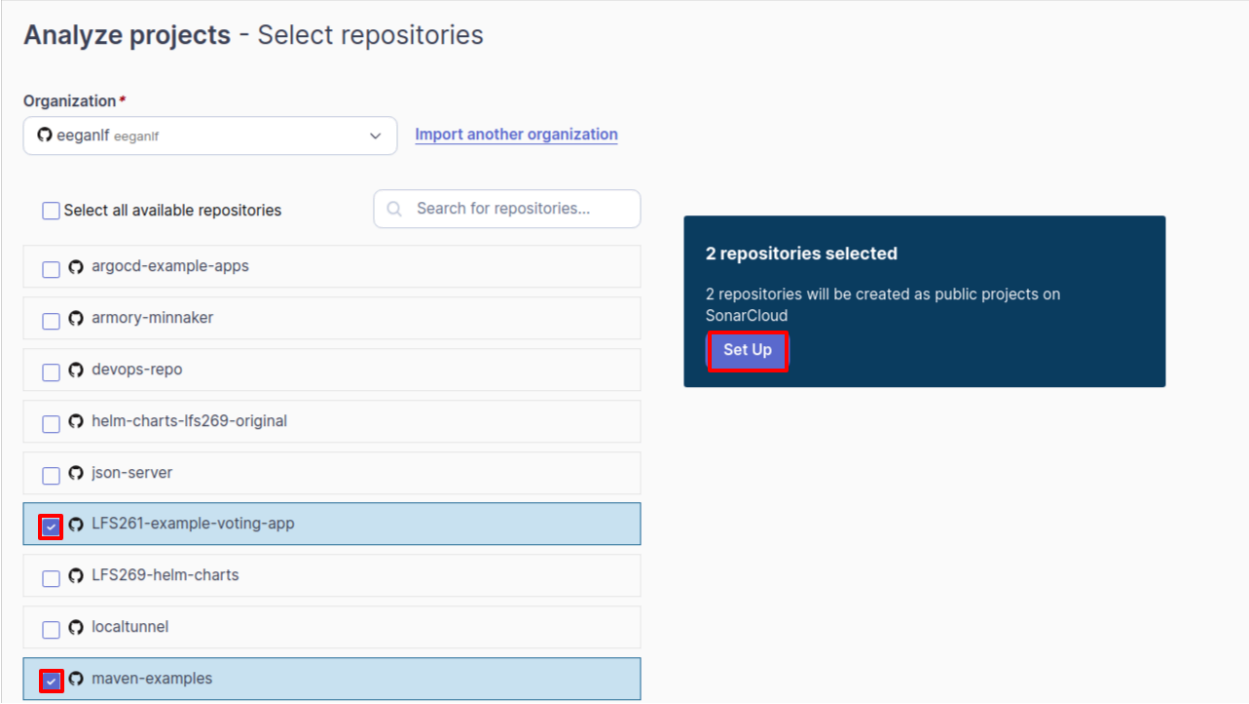
to use it as a reference later when you integrate it with Jenkins. Your GitHub username should be auto-populated. If not, enter it into the **Key** box. Click **Continue**.



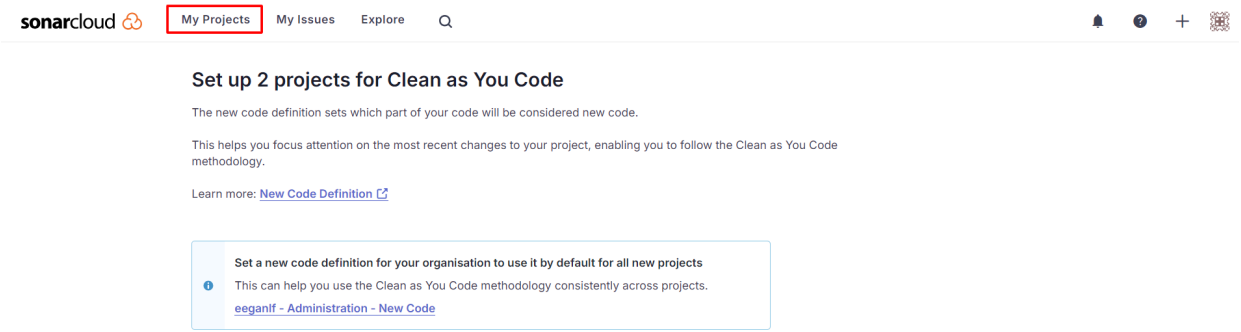
Since your repository is public, you can proceed with the free plan.



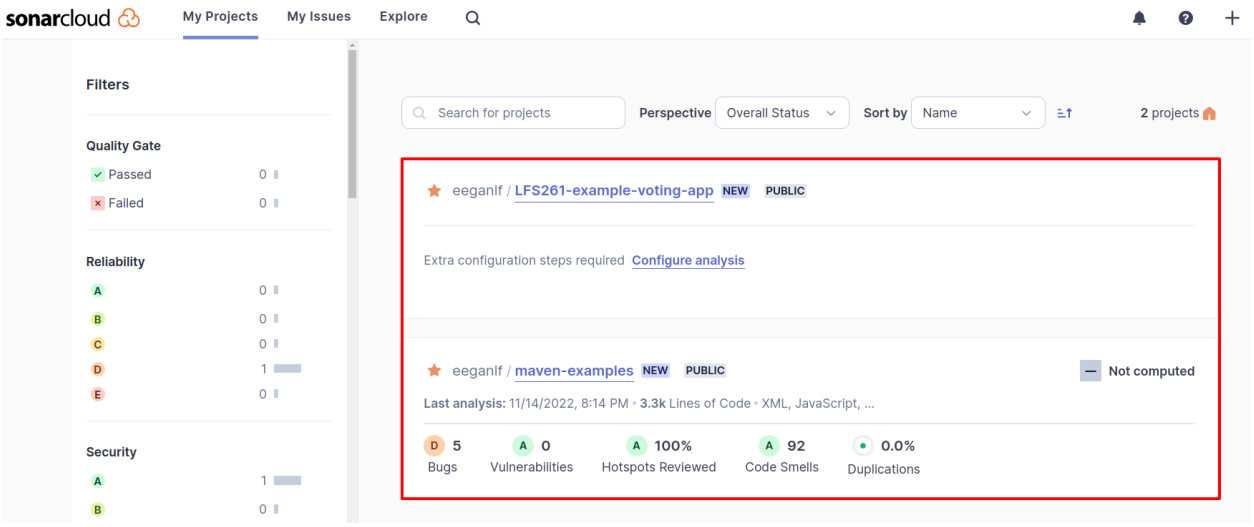
Choose the repositories that you want to analyze with SonarQube. Select `maven-examples` and the `example-voting-app`. Click **Set Up**:



If you are not redirected to your **My Projects** page in SonarCloud, navigate there now via the **My Projects** link.



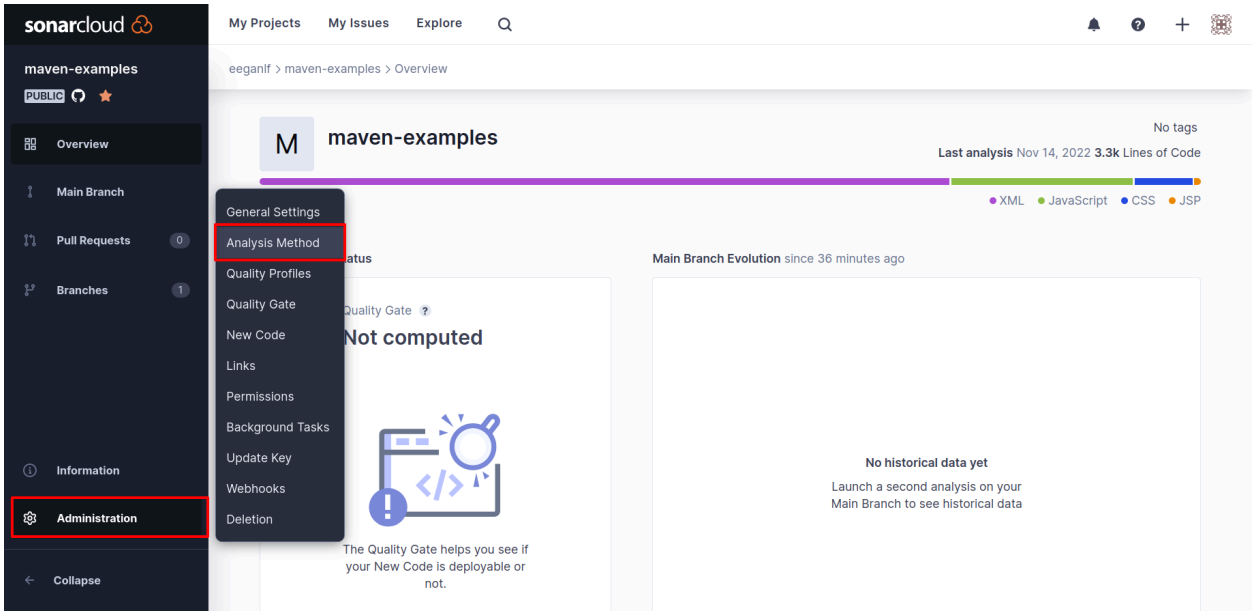
This is the page that lists all of your projects.



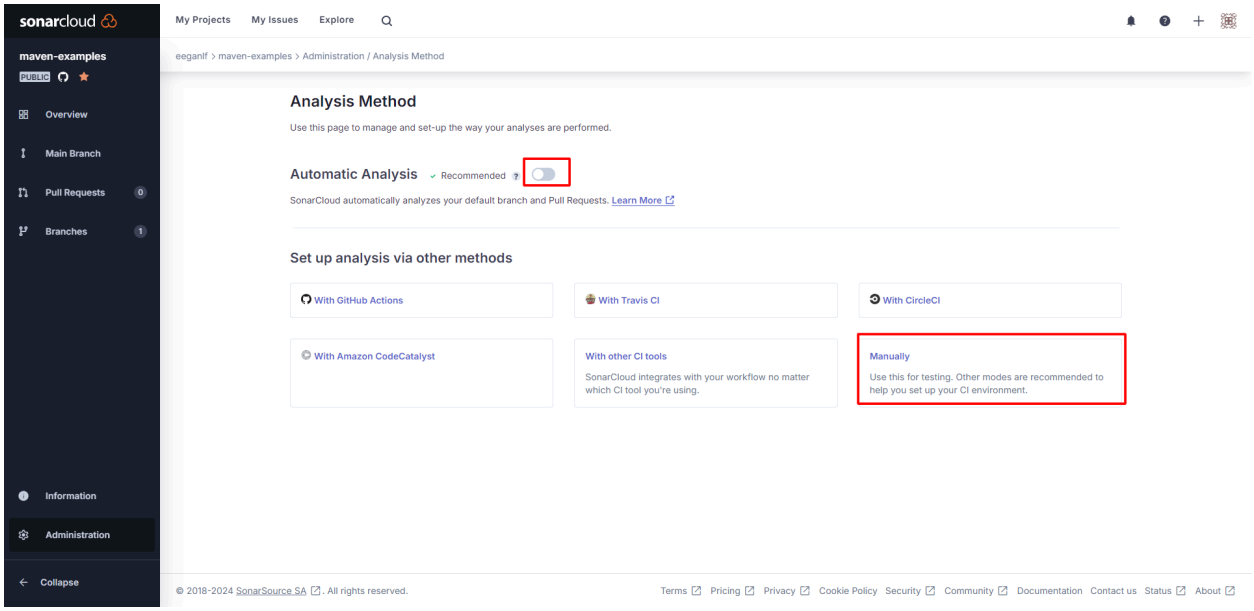
Click on the **maven-examples** project:

You will be taken to the **maven-examples** project page. You must disable automatic analysis as you want Jenkins to tell SonarCloud when to analyze your code.

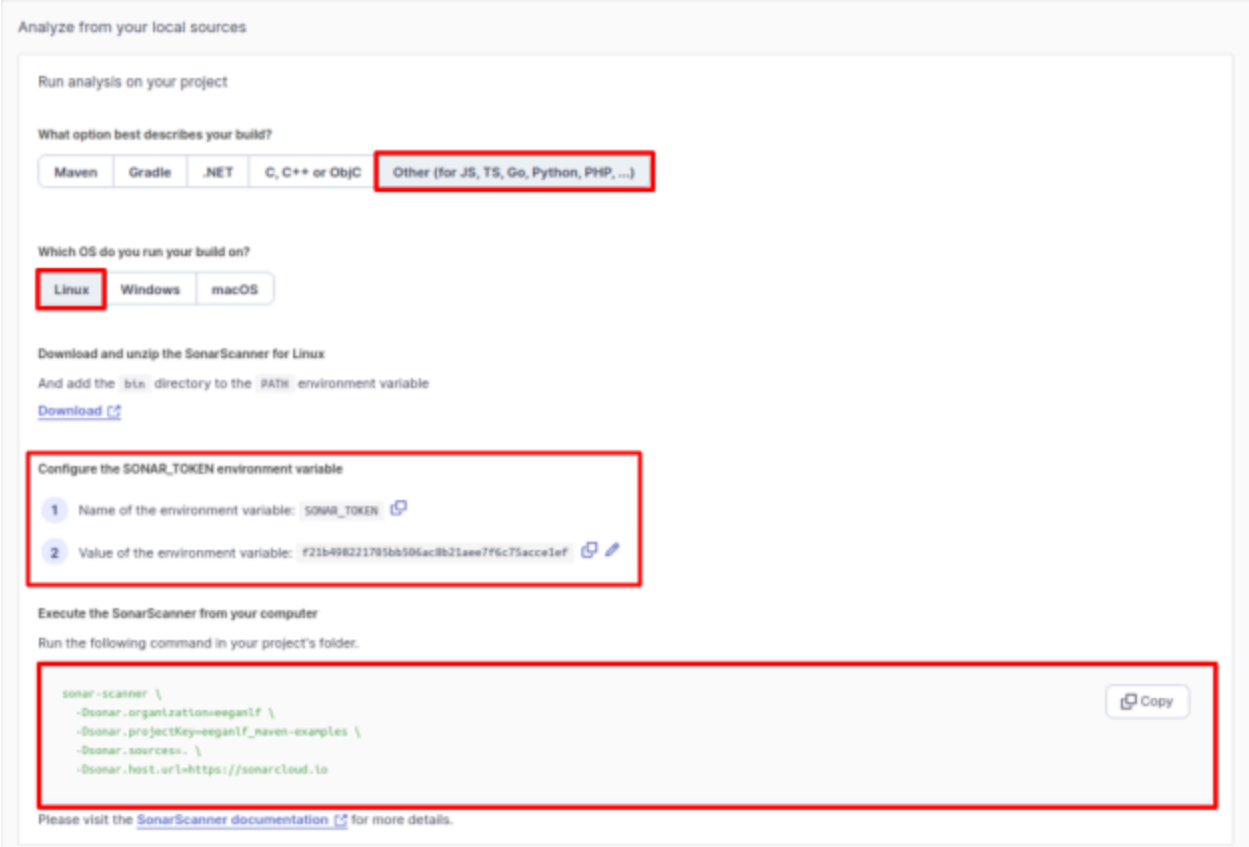
You must also configure your project. To accomplish this, click navigate to **Administration > Analysis Method.**



Uncheck **Automatic Analysis** and click **Set up analysis via other methods > Manually**:



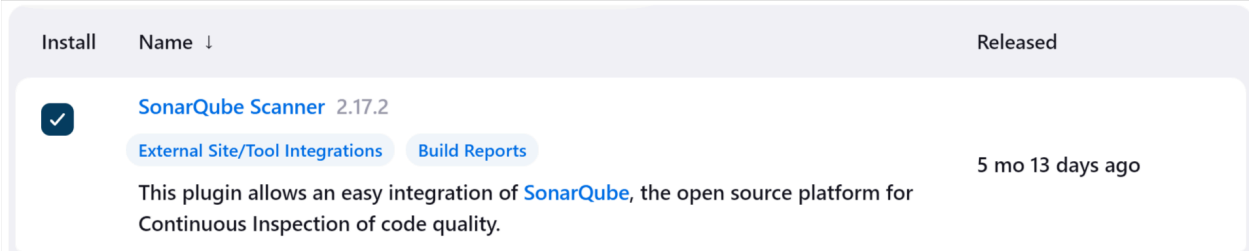
Under **What option best describes your build?** select **Other**. Select **Linux** for the operating system.



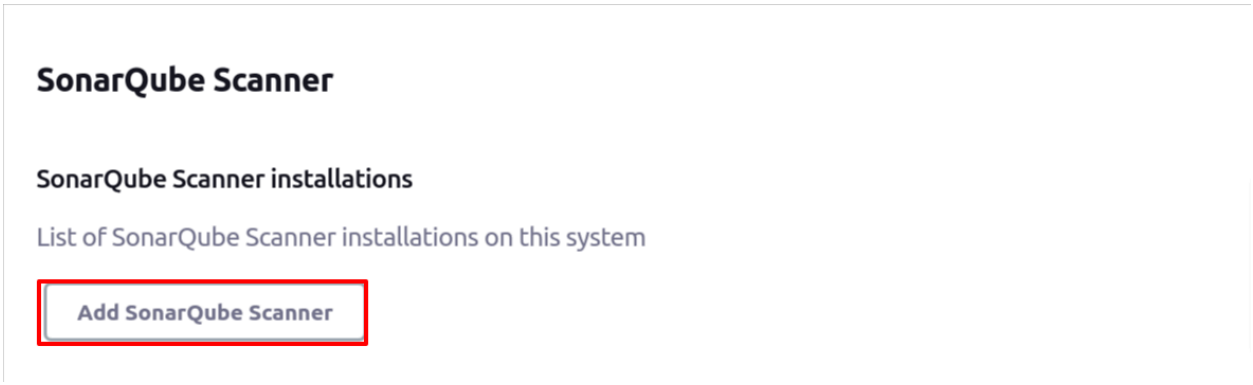
Notice that a command is generated. This command contains configuration properties that we will use to integrate SonarQube with Jenkins.

Integrate SonarQube with Jenkins

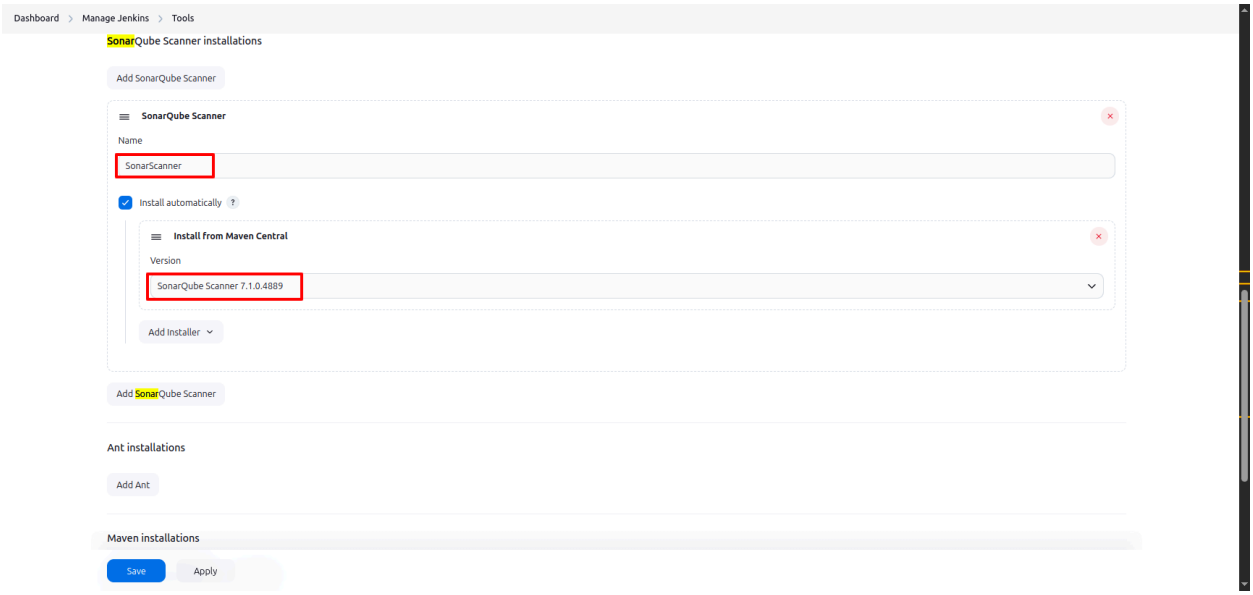
Install the SonarQube Scanner plugin for Jenkins.



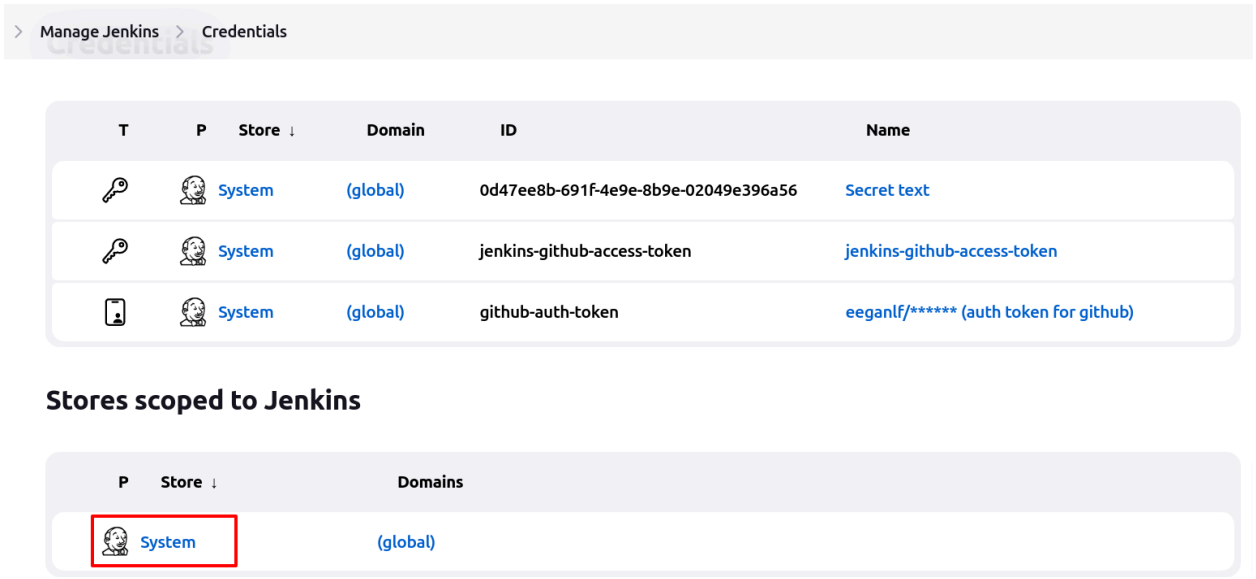
From **Jenkins > Manage Jenkins > Tools > SonarQube Scanner** click **Add SonarQube Scanner**:



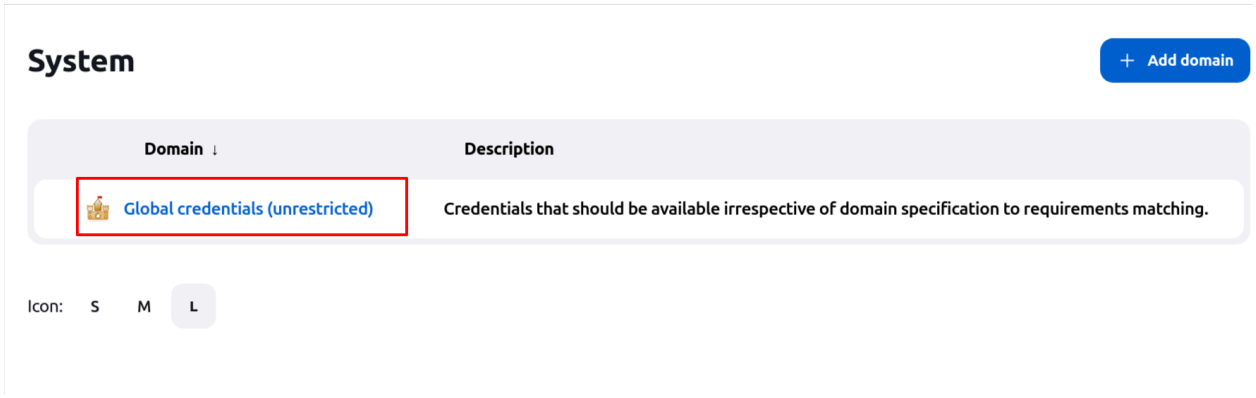
Name the SonarQube Scanner **SonarScanner** which will be referred to later when you write the pipeline code. Also, choose whichever is the latest version, which should be automatically selected from the dropdown menu:



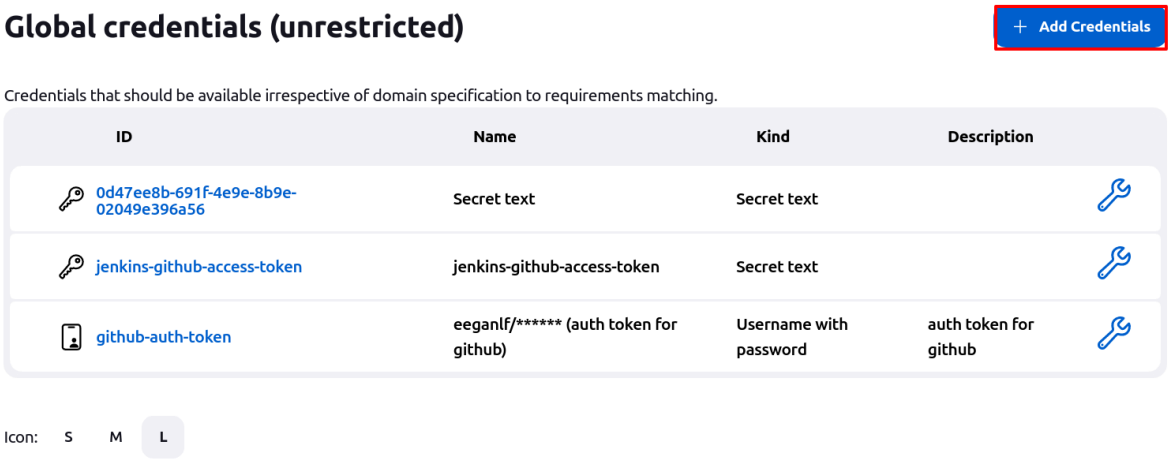
From the Jenkins home, navigate to **Manage Jenkins > Security > Credentials**:



Click **Global credentials (unrestricted)**:

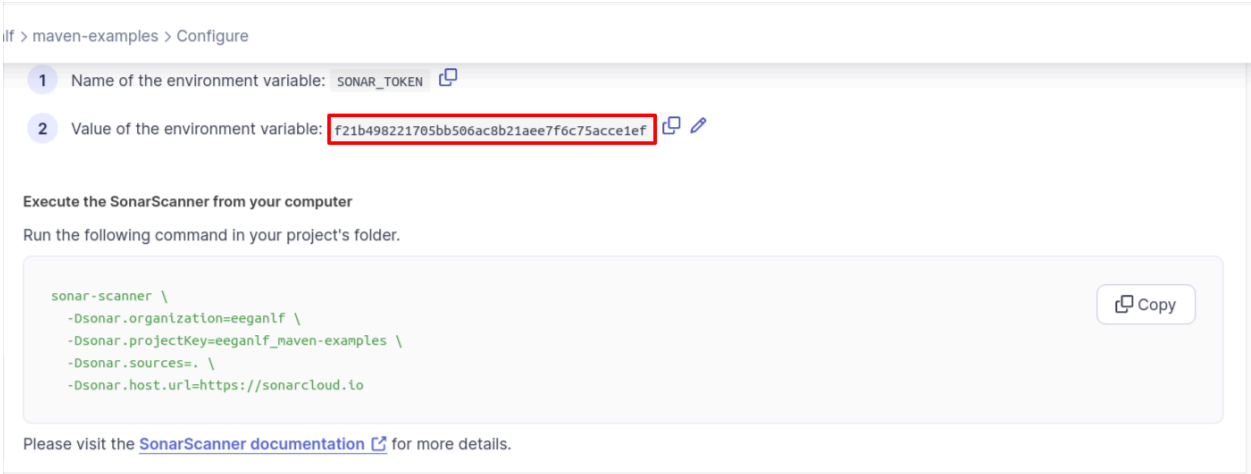


Click **Add Credentials**:



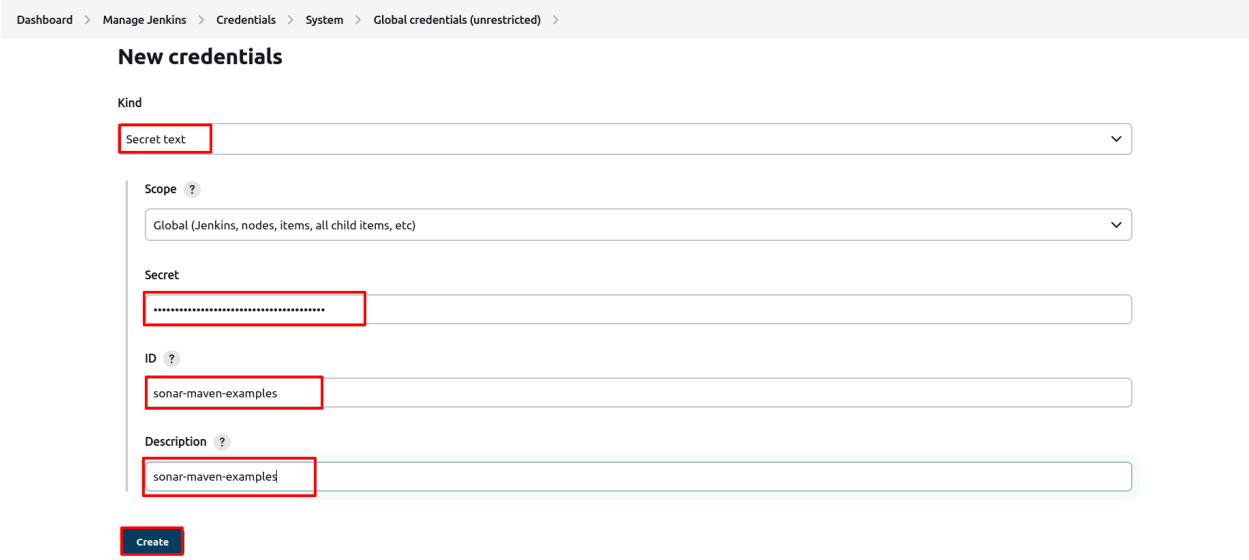
Add new credentials with:

- Kind “Secret text”.
- Copy the value for the `SONAR_TOKEN` found on the configuration page on SonarCloud for the `maven-examples` project:

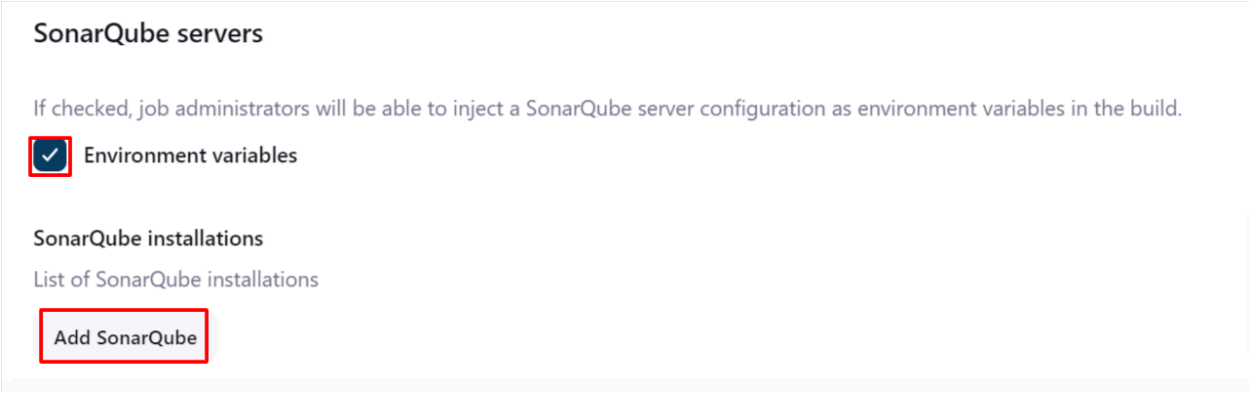


- Paste it in the “Secret” field on Jenkins.
- Add ID and Description as `sonar-maven-examples`.

Refer to the following screenshot while adding credentials:



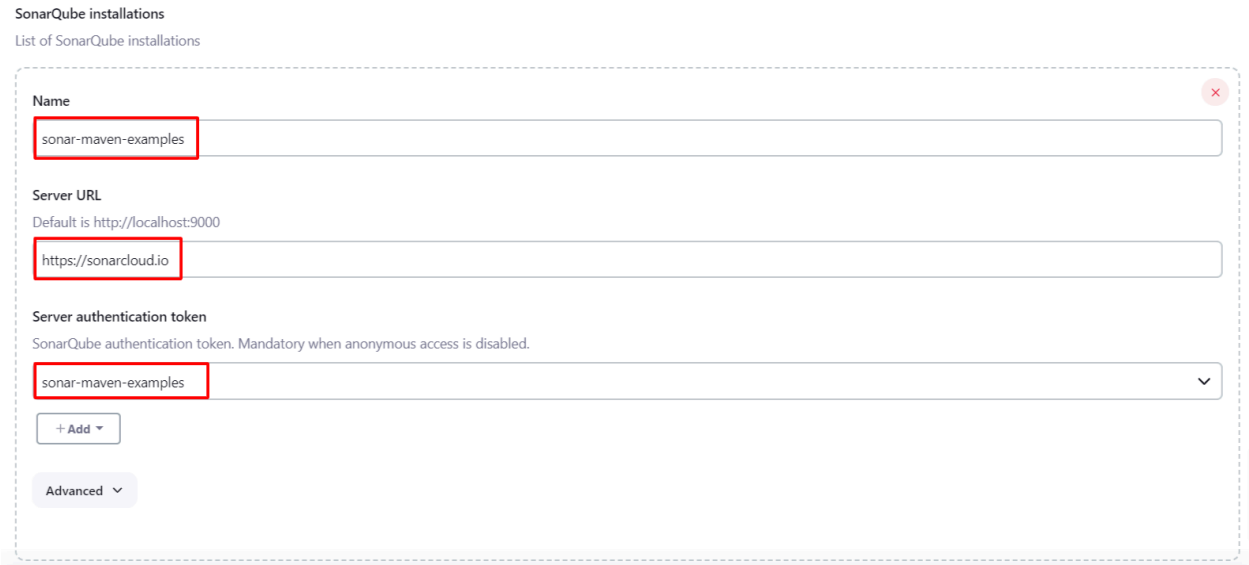
Now navigate to **Jenkins > Manage Jenkins > System > SonarQube Servers** and add a new entry.



Provide the configuration as shown below:

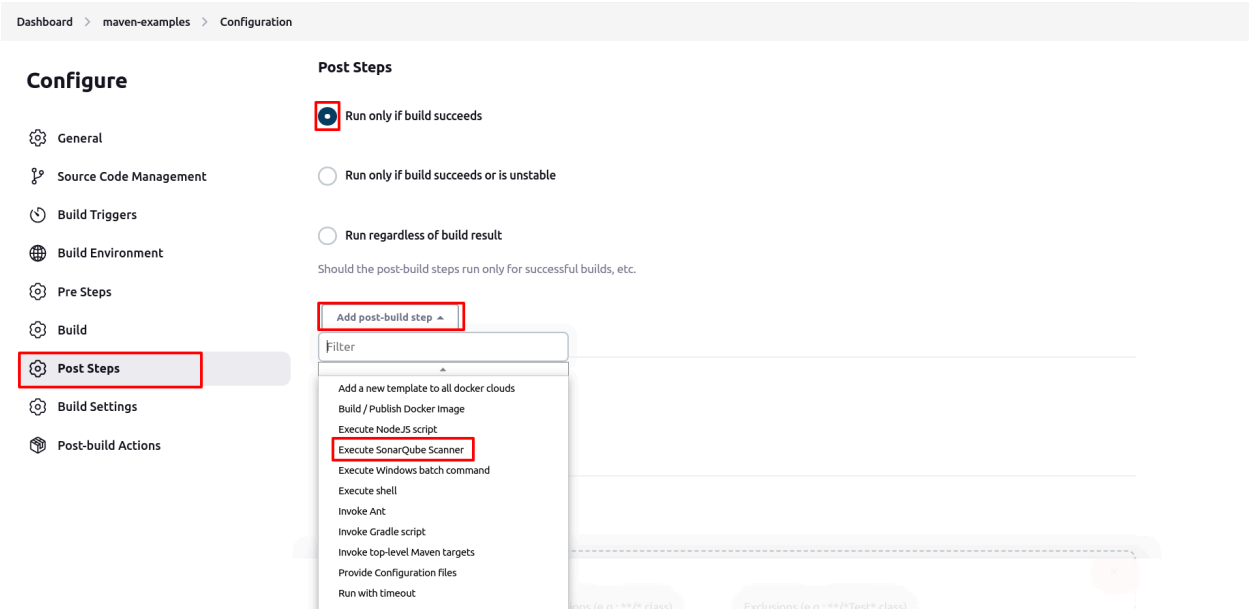
- Check the **Environment Variables** box to enable injection of configurations.
- Name this instance **`sonar-maven-examples`** as it will be referred to later.
- Use the SonarQube URL but do **NOT** include a trailing slash or it will not work.
- Select the credentials you added in the previous step from the dropdown, i.e. *sonar-maven-examples*.

- Save the configuration.



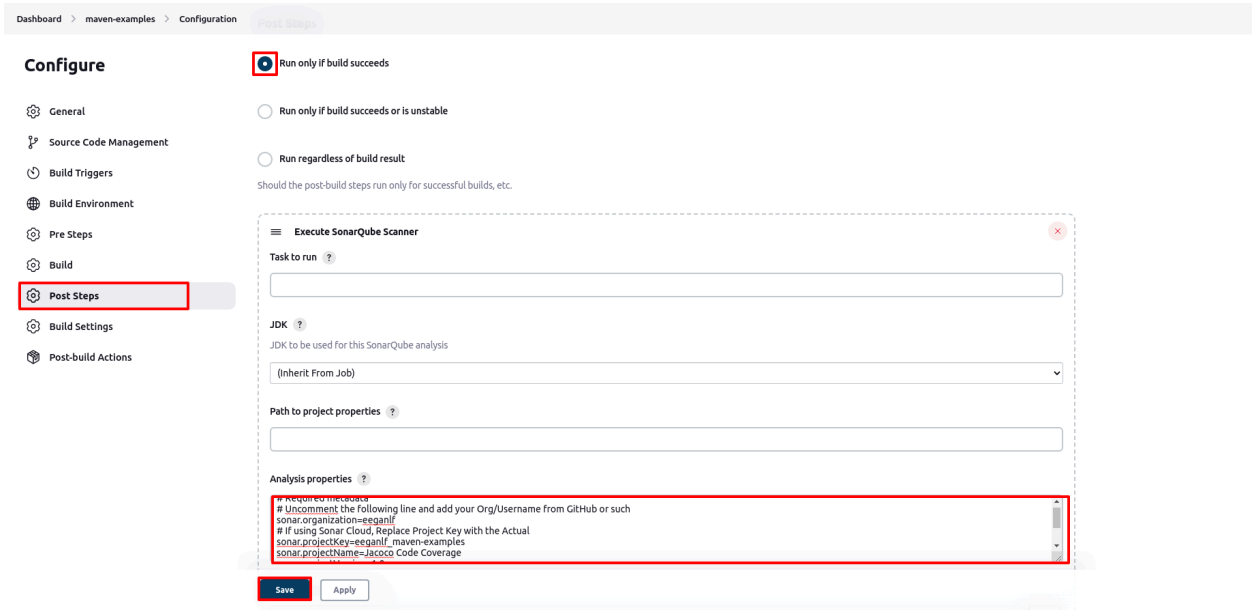
Scanning Code and Reporting to SonarQube

In Jenkins, go to the configuration page for the **`maven-examples`** job that you created to use code coverage and add a post build step. Select **Execute Sonarqube Scanner**.

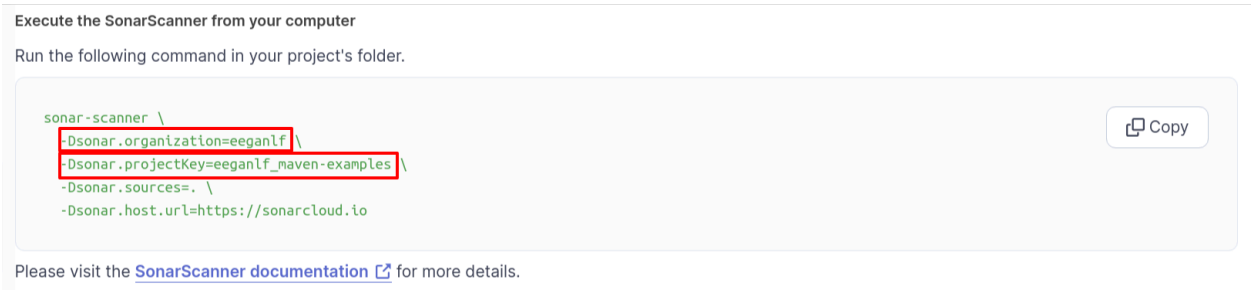


Put the following snippet into the **Analysis properties** text box:

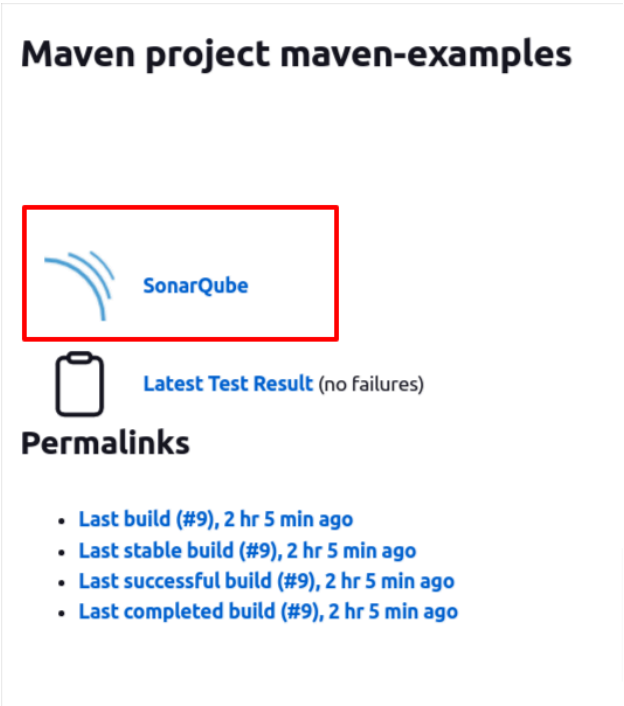
```
# Required metadata
# Uncomment the following line and add your Org/Username from GitHub
or such
sonar.organization=YourGitHubOrg
# If using Sonar Cloud, Replace Project Key with the Actual

sonar.projectKey=yourGitHubOrg_ProjectName
sonar.projectName=Jacoco Code Coverage
sonar.projectVersion=1.0
# Comma-separated paths to directories with sources (required)
sonar.sources=code-coverage-jacoco/src/main
# Encoding of the source files
sonar.sourceEncoding=UTF-8
sonar.java.binaries=.
sonar.coverage.jacoco.xmlReportPaths=code-coverage-jacoco/target/site/
jacoco-ut/jacoco.xml
```



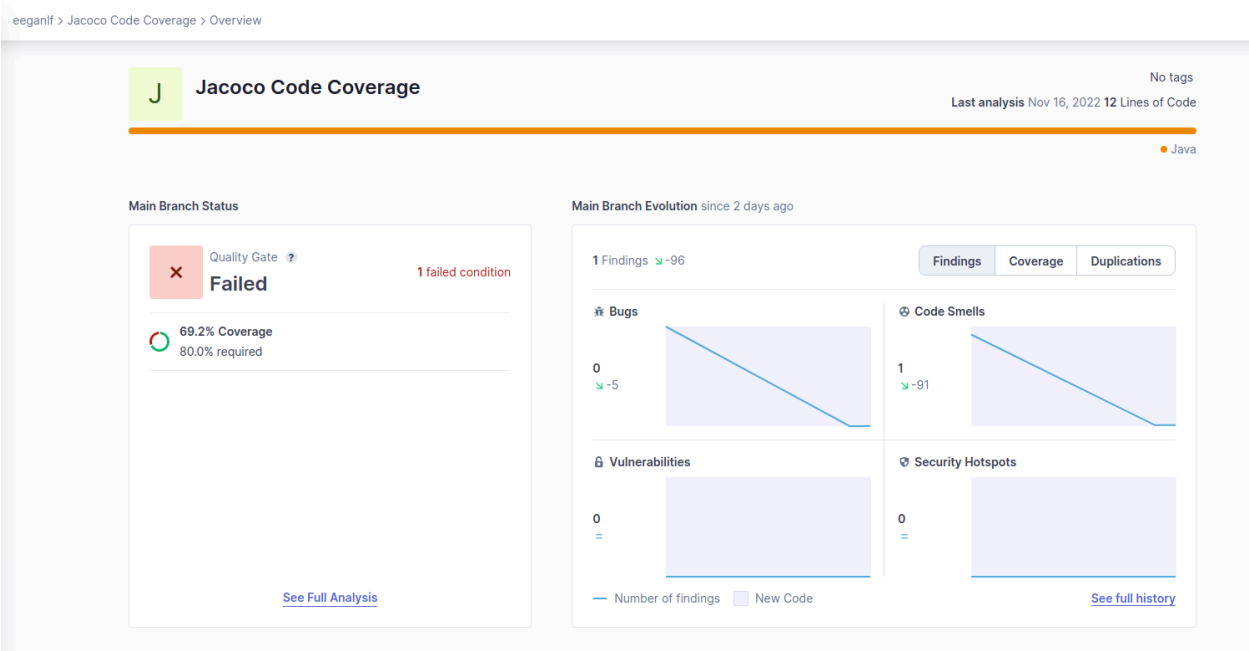
Ensure you replace the properties for `sonar.organization` and `sonar.projectKey` with what you see in the **Sonar Cloud Analysis Configuration** page:



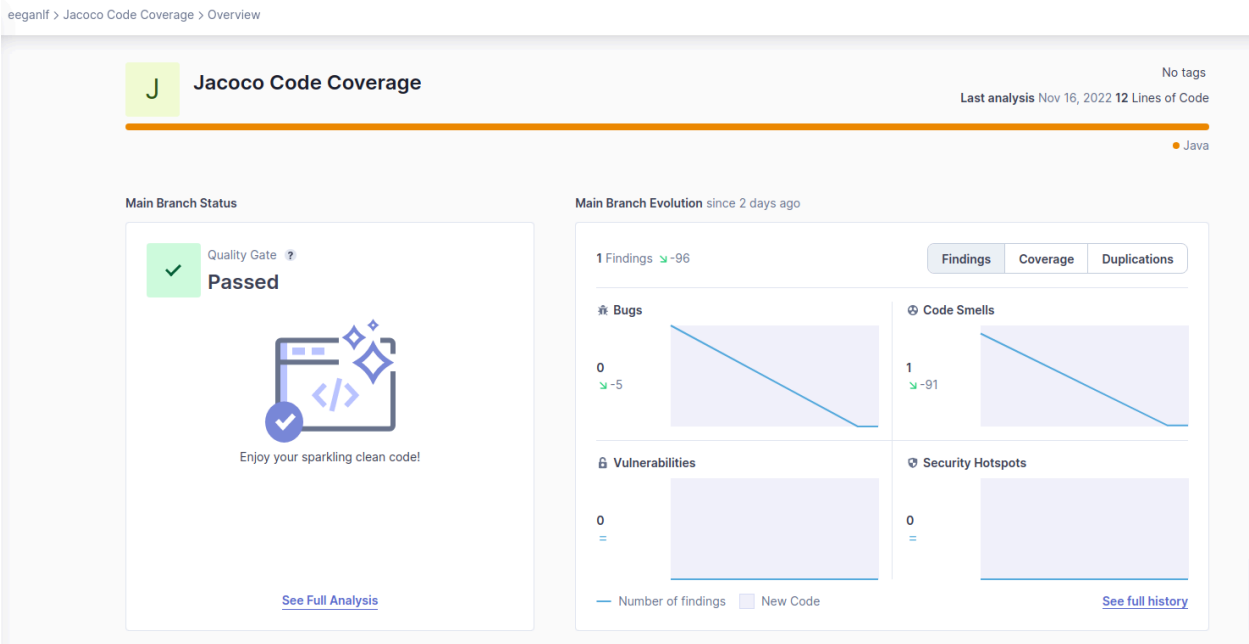
Back in Jenkins, build the project. Click the SonarQube link to navigate to SonarQube:



You will see that sonarcloud.io shows that the project failed and displays the reason why it failed. In this case, it failed because we have less than 80% test coverage.



Back on the GitHub repository for **`maven-examples`**, merge the **`ut2`** branch into the master and run **Build Now** in Jenkins on the **`maven-examples`** job. After it is complete, follow the **SonarQube** link. The job should now be displayed as passed:



Note that this does not keep Jenkins from successfully building the job. It is an illustration of

how quality gates can be configured to output a pass or fail result for a particular job. We do, however, want to enable SonarQube to fail builds before they get to production. We can and should do this in the Jenkinsfile. We will accomplish this in the next section for the **`example-voting-app`**.

Adding SonarQube Scanner Stage to Jenkinsfile

You want SonarQube to fail the pipeline before the project is deployed if the code does not pass analysis. Add the following code snippet to the consolidated Jenkinsfile created earlier while setting up a monopipe. Place the code above the **`stage ('deploy to dev')`** block of code.

`file: example-voting-app/Jenkinsfile`

```
    stage('Sonarqube') {
      agent any
      when{
        branch 'master'
      }
            environment{
        sonarpath = tool 'SonarScanner'
      }

      steps {
            echo 'Running Sonarqube Analysis..'
            withSonarQubeEnv('sonar-instavote') {
              sh "${sonarpath}/bin/sonar-scanner
-Dproject.settings=sonar-project.properties
-Dorg.jenkinsci.plugins.durabletask.BourneShellScript.HEARTBEAT_CHECK_
INTERVAL=86400"
            }
      }
    }


    stage("Quality Gate") {
        steps {
            timeout(time: 1, unit: 'HOURS') {
                // Parameter indicates whether to set pipeline to
UNSTABLE if Quality Gate fails
                // true = set pipeline to UNSTABLE, false = don't
                waitForQualityGate abortPipeline: true
            }
        }
    }
```

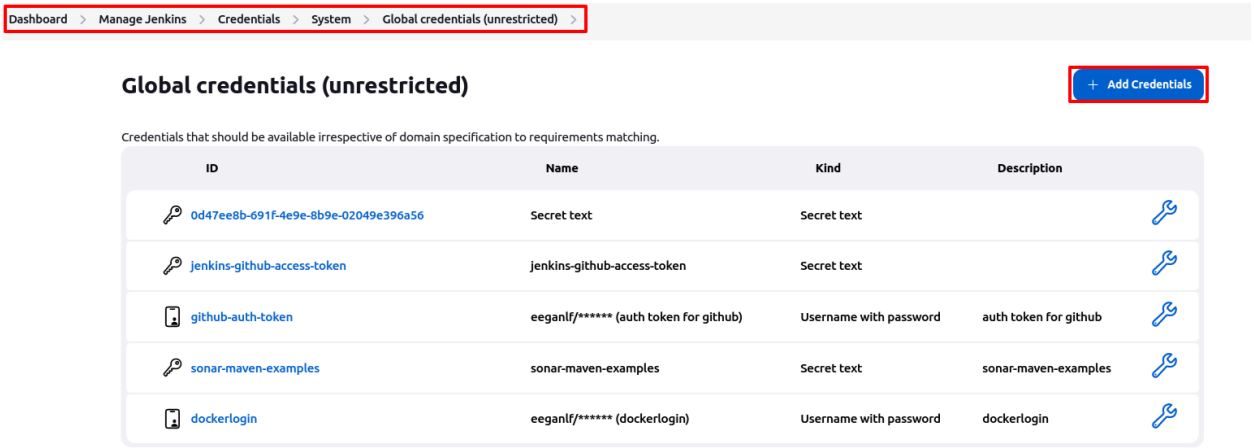
You can access this snippet here.

Also update `sonar-project.properties` file at the root of `example-voting-app` repository with *your* organization and project key as per configured on SonarCloud.

File: `example-voting-app/sonar-project.properties`

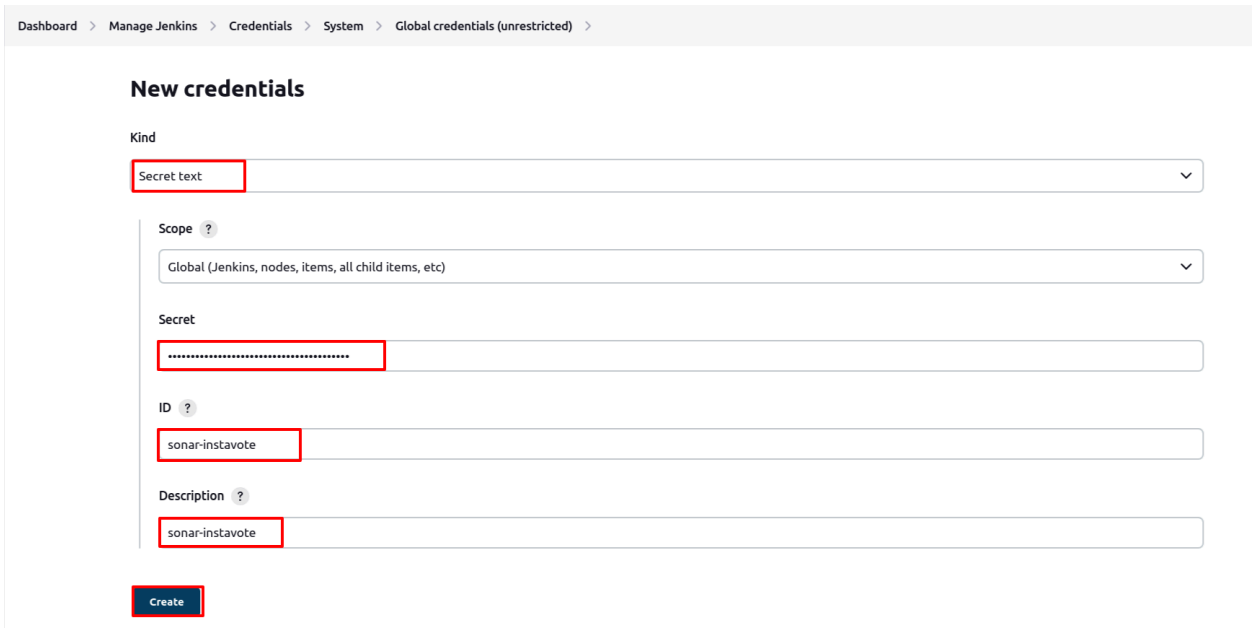
```
# Uncomment and update Org matching your configurations on Sonarcloud
sonar.organization=your-org
sonar.projectKey=your-org_example-voting-app
sonar.projectName=LFS261 example voting app
sonar.projectVersion=1.0

# Comma-separated paths to directories with sources (required)

sonar.sources=worker

# Encoding of the source files

sonar.sourceEncoding=UTF-8

sonar.java.binaries=worker

sonar.coverage.jacoco.xmlReportPaths=worker/target
```

You also need to add Credentials to connect to the project added to SonarCloud. Navigate to **Jenkins > Manage Jenkins > Credentials > System > Global credentials (unrestricted)** and click **Add Credentials**:

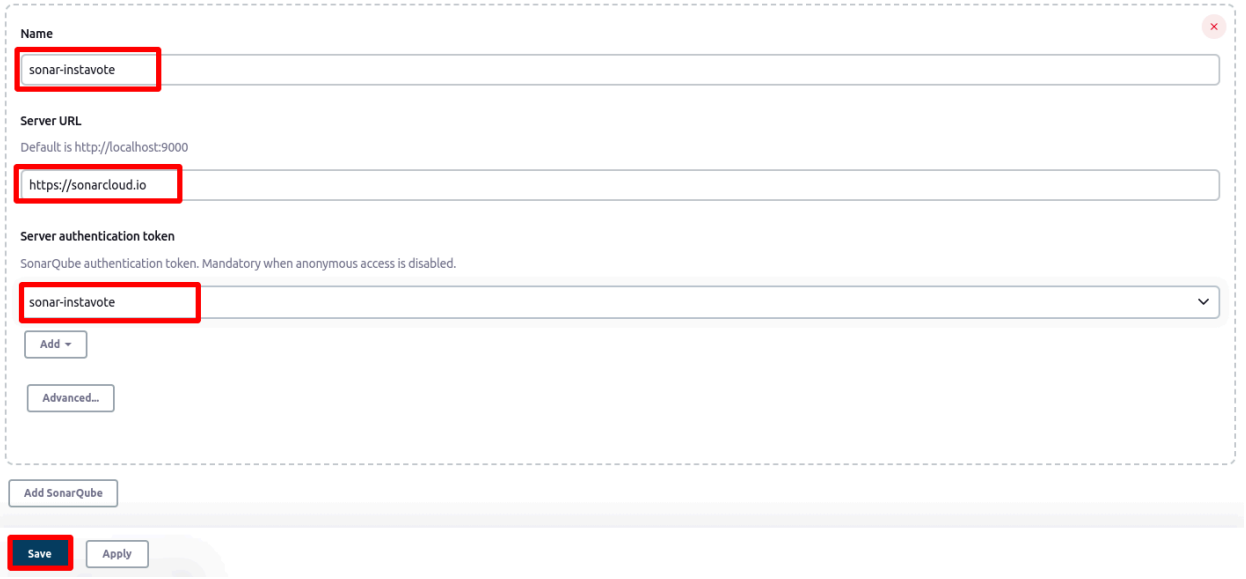


Find the **SONAR_TOKEN** on the **LFS261-example-voting-app** configuration page and copy it:

Paste this token into the **Secret** text box while configuring the credentials:



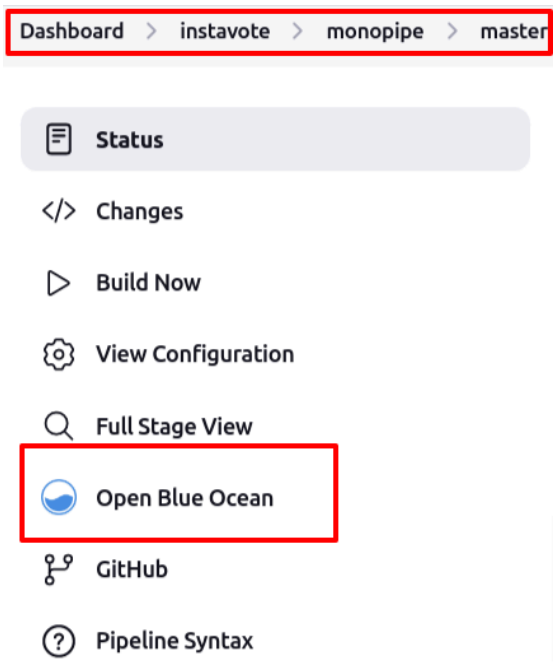
Create a new SonarQube Server configuration from **Jenkins > Manage Jenkins > System > SonarQube Servers**.



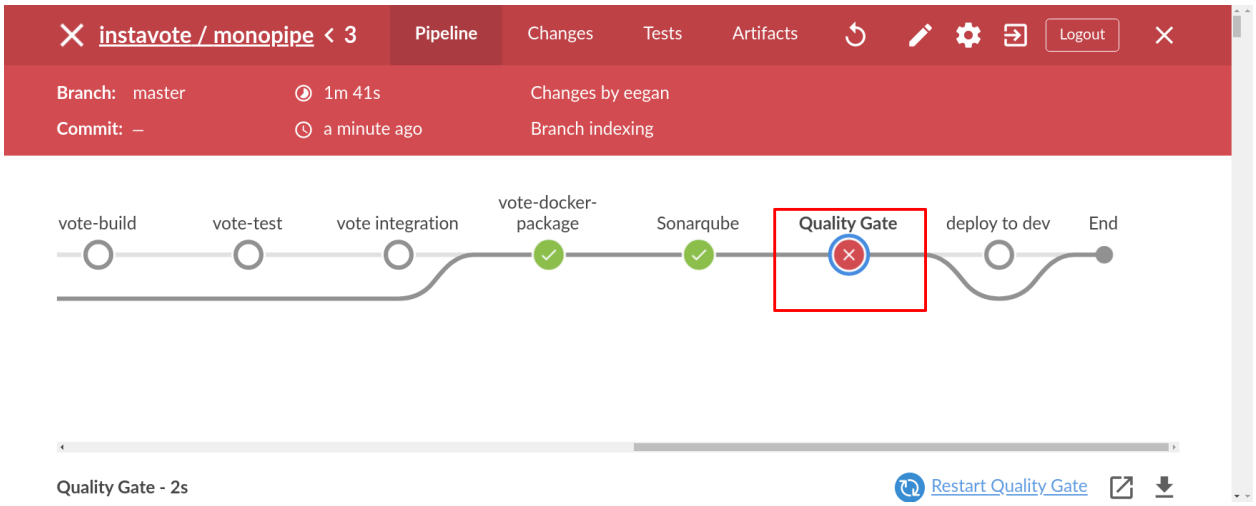
Remember to make sure that the `https://sonarcloud.io` does **NOT** have a trailing slash.

The free quality gate provided by SonarCloud only performs analysis on 20 lines or more of new code. Replace the entirety of the `example-voting-app/worker/src/main/java/worker/Worker.java` file with this code.

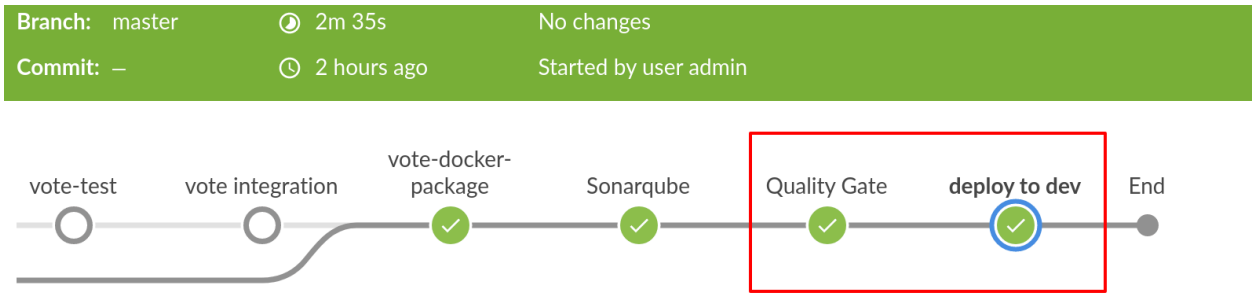
Commit to the master branch and observe the latest jobs being run with the next instance of the pipeline run. To view the build in the alternate BlueOcean interface, select the interface from the side menu of the master branch:



After the master branch builds in the monopipe job, you will notice that it fails at the **Quality Gate** step:



To get our worker app to pass the quality gate, we need to provide test coverage greater than 80%. Replace `LFS261-example-voting-app/worker/src/test/java/worker/UnitWorker.java` with this code.



Adding Integration Tests

Integration tests for the **vote** Python app are already added to the `vote/` subdirectory of the repository. To add integration tests to the pipeline, follow the steps below.

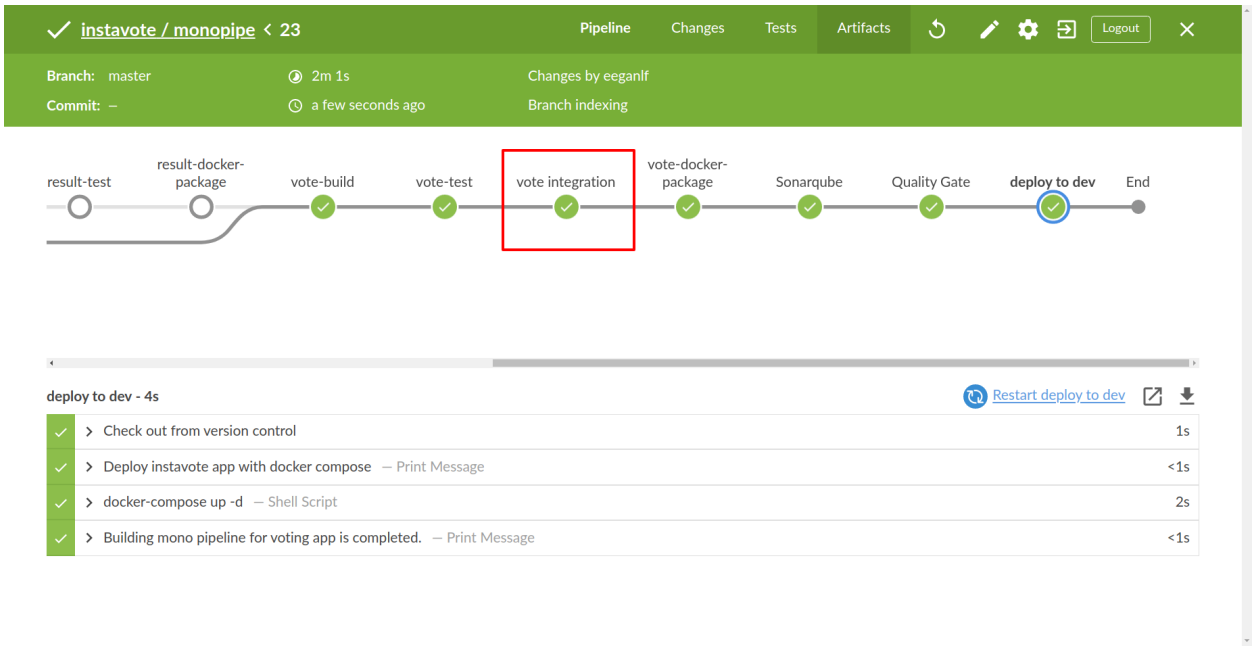
Examine the script at `vote/integration_test.sh` in the `example-voting-app` repository. Reading the script and the docker compose setup it uses should give you a good understanding of how integration tests are set up. Add a stage to the Jenkinsfile to run the integration tests as follows. Place the below code block just after the stage **vote-test** stage which runs unit tests for the **vote** app:

`file: example-voting-app/Jenkinsfile`

```
stage('vote integration'){
    agent any
    when{
      changeset "**/vote/**"
      branch 'master'
    }
    steps{
      echo 'Running Integration Tests on vote app'
      dir('vote'){
        sh 'sh integration_test.sh'
      }
    }

}
```

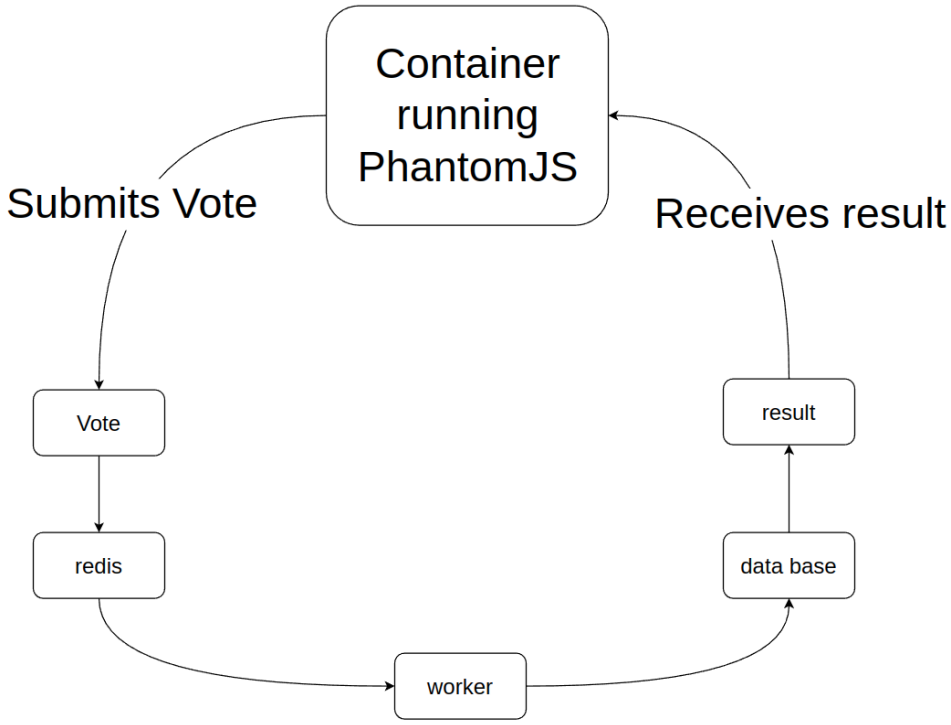
You should see a similar output in the Blue Ocean interface as the screenshot below. This

indicates a successful execution of integration tests for the `vote` app:



E2E Tests

Examine the script `example-voting-app/e2e.sh` in the `example-voting-app` repository as well as the `example-voting-app/e2e/docker-compose.yml`. You do not need to understand all of the code, but reading the script and the Docker Compose setup it uses will give you a better understanding of how e2e tests are set up.



The `.env` File

`example-voting-app/e2e/docker-compose.yml` uses environment variables to decide which images to use to spin up the containers for the e2e tests.

Inside the `example-voting-app/e2e/.env` file you will find the following:

```
VOTE_IMAGE=xxxx/vote:latest
WORKER_IMAGE=xxxx/worker:latest
RESULT_IMAGE=xxxx/result:latest
```

Replace `xxxx` with your own Docker Hub user ID.

Setting Up E2E

Once the `.env` file is edited, run the following command from inside the `example-voting-app/e2e` which contains the `docker-compose.yml` file:

```
docker compose build
```

This will build the images necessary for the e2e test. It also ensures that any changes made to testing files are picked up by Docker Compose. After everything is built, run:

```
docker compose up -d
```

```
[+] Running 8/8
 ⠿ Network e2e_back-tier   Created                                0.1s
 ⠿ Network e2e_front-tier  Created                                0.1s
 ⠿ Container e2e-db-1      Started                                1.8s
 ⠿ Container e2e-redis-1   Started                                1.9s
 ⠿ Container e2e-worker-1  Started                                2.8s
 ⠿ Container e2e-vote-1    Started                                3.1s
 ⠿ Container e2e-result-1  Started                                3.4s
 ⠿ Container e2e-e2e-1     Started                                3.9s
```

To list your running containers to find their associated ports, run:

```
sudo docker ps
```

```
IMAGE                       PORTS
xxxxxxx/result:latest       0.0.0.0:49156->80/tcp, :::49156->80/tcp
xxxxxxx/vote:latest         0.0.0.0:49155->80/tcp, :::49155->80/tcp
```

Find the containers associated with the **`result:latest`** image and the **`vote:latest`** image. Visit **`IPADDRESS:VOTECONTAINERPORT`** and **`IPADDRESS:RESULTCONTAINERPORT`**. Submit a vote. This is manual e2e testing.

To automate the process, we will now spin up the e2e service, which will automatically submit a vote for you. The e2e service is listed in the **`example-voting-app/e2e/docker-compose.yml`**. Run:

```
docker compose run --rm e2e
```

```
-----------------
Current Votes Count: 13
-----------------

I: Submitting one more vote...

-----------------
New Votes Count: 14
-----------------

I: Checking if votes tally......
```

```
------------
Tests passed
------------
```

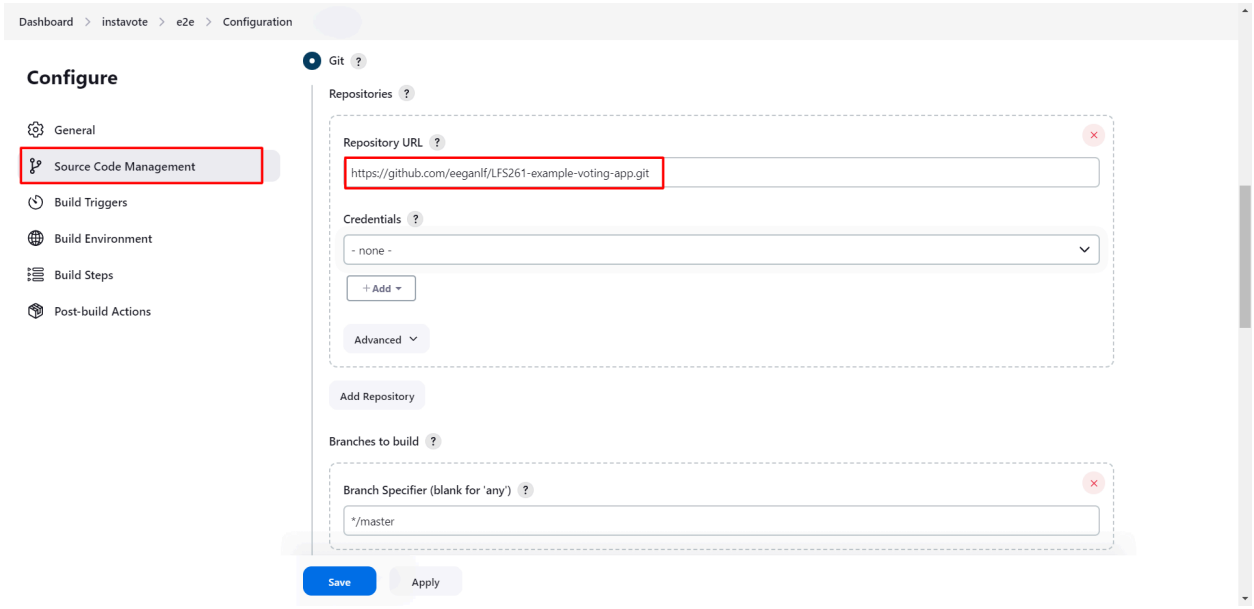
You should see something similar to the output above, though your counts will differ. If it fails, try running it again, and it should pass. This means that the application passed e2e testing. Shut the application down with the following command from inside `example-voting-app/e2e`:

```
docker compose down
```

Using a container to test our application is the first building block to integrating the e2e test into our CI process, which we will do next.

Integrating E2E Tests with Jenkins

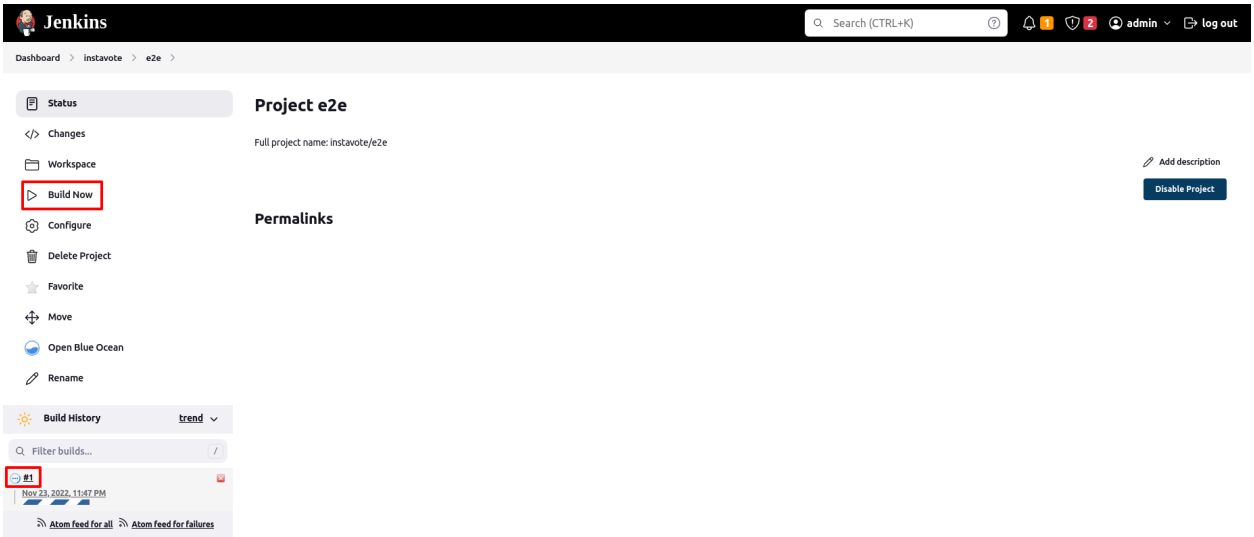
First, create a freestyle project called e2e in Jenkins. Add the Git repository:



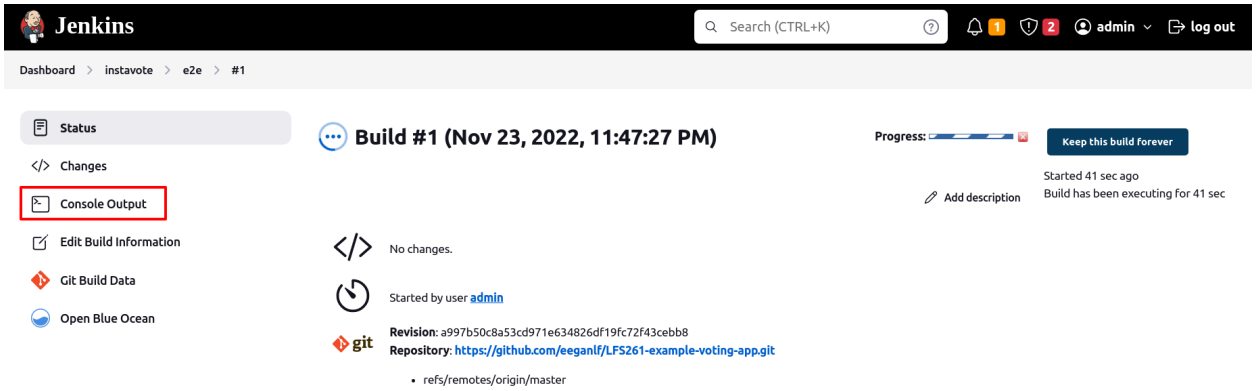
Inside the **Build Steps > Add build step > Execute shell > Command input** box paste: `./e2e.sh`

Save the configuration.

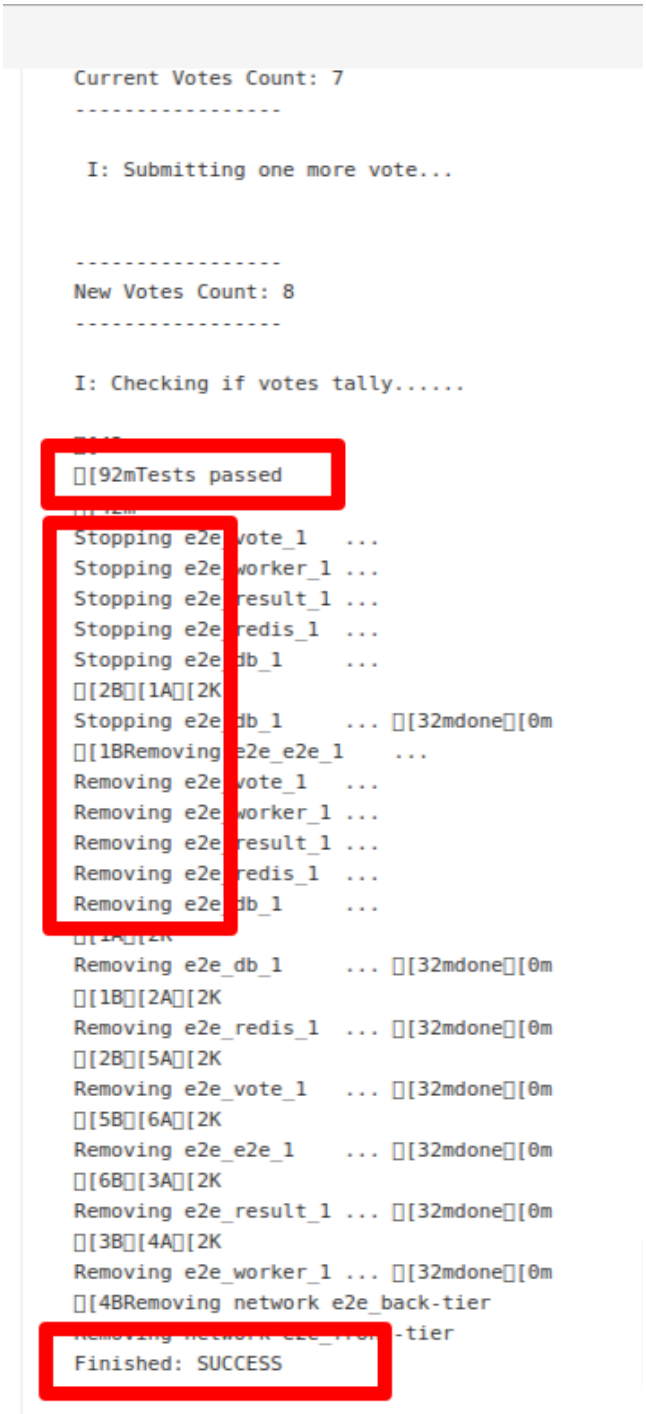
Run the job and click the build:



Click **Console output** to see the console output:



If the tests fail, try running the job twice more. You should ultimately see something like the following:



You should see that the tests passed and then you should see the containers being cleaned up with a `SUCCESS` message at the bottom of the output. You have successfully run e2e tests with Jenkins.

Summary

In this lab, we integrated Jacoco into Jenkins to obtain automatic testing coverage analysis. We then integrated SonarQube into Jenkins for automatic code analysis. Finally, we added integration and e2e tests into Jenkins.

Lab 10. Running Containers at Scale with Kubernetes

By the end of this lab exercise, you should be able to:

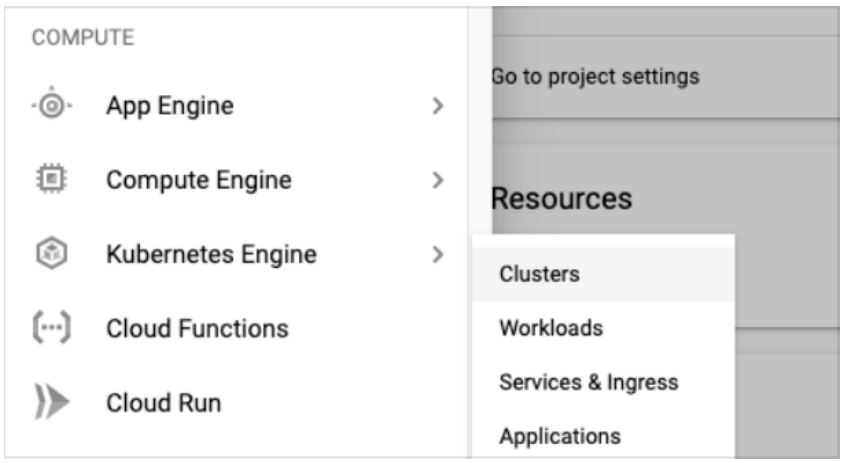
- Set up a managed Kubernetes environment with Google Cloud
- Set up a **`kubectl`** client, connect and work with the Kubernetes cluster
- Deploy applications to the Kubernetes cluster and expose them as services

Set Up Kubernetes Cluster with GCP

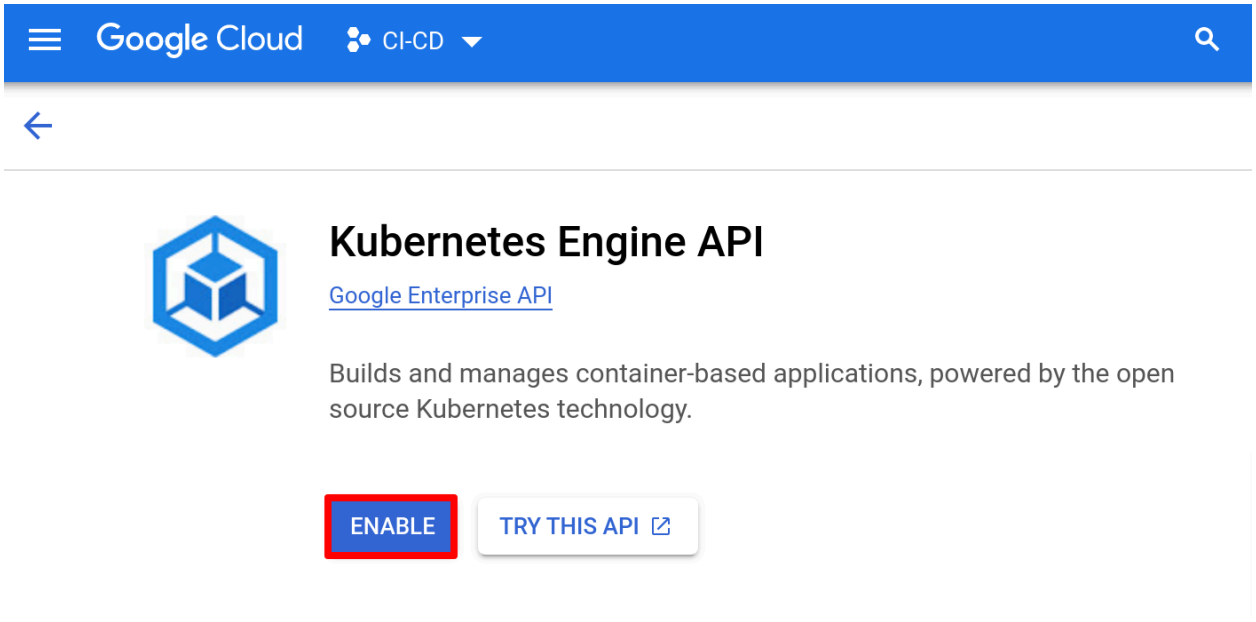
Set up a Google Cloud account by browsing to https://cloud.google.com/free.

Once setup, login to your account and browse to the cloud console by visiting https://console.cloud.google.com/.

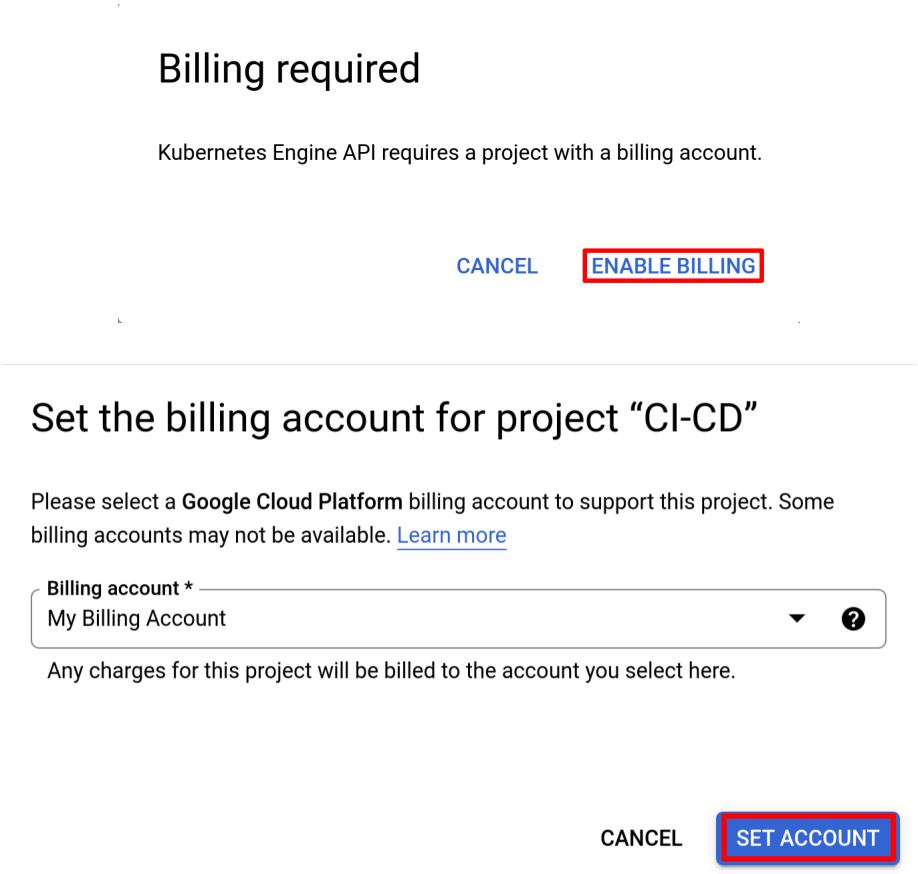
From **Navigation** select **View All Products > Compute > Kubernetes Engine > Clusters**.



If it asks you to enable Kubernetes Engine API, do so by clicking on the **Enable** button.

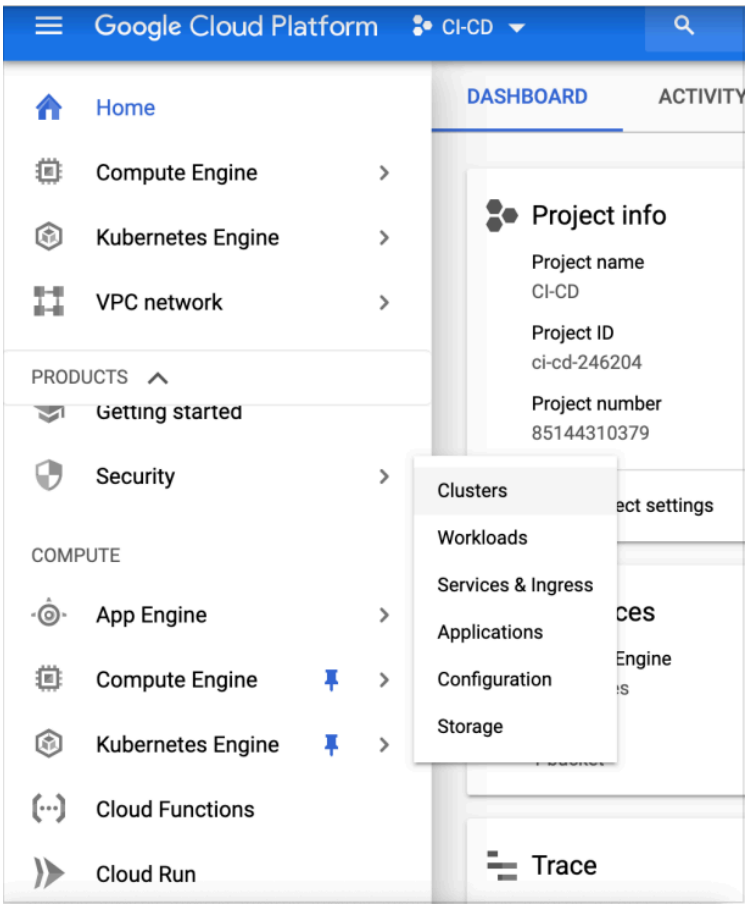


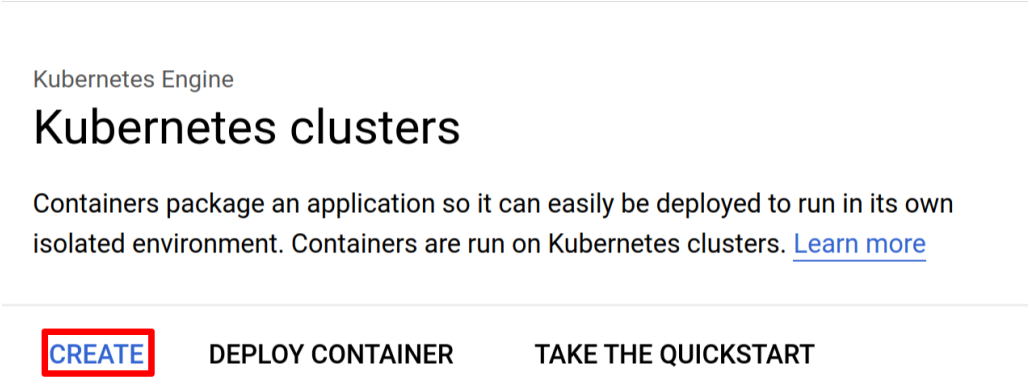
You may also be asked to set up a Billing Account, which you should set up.



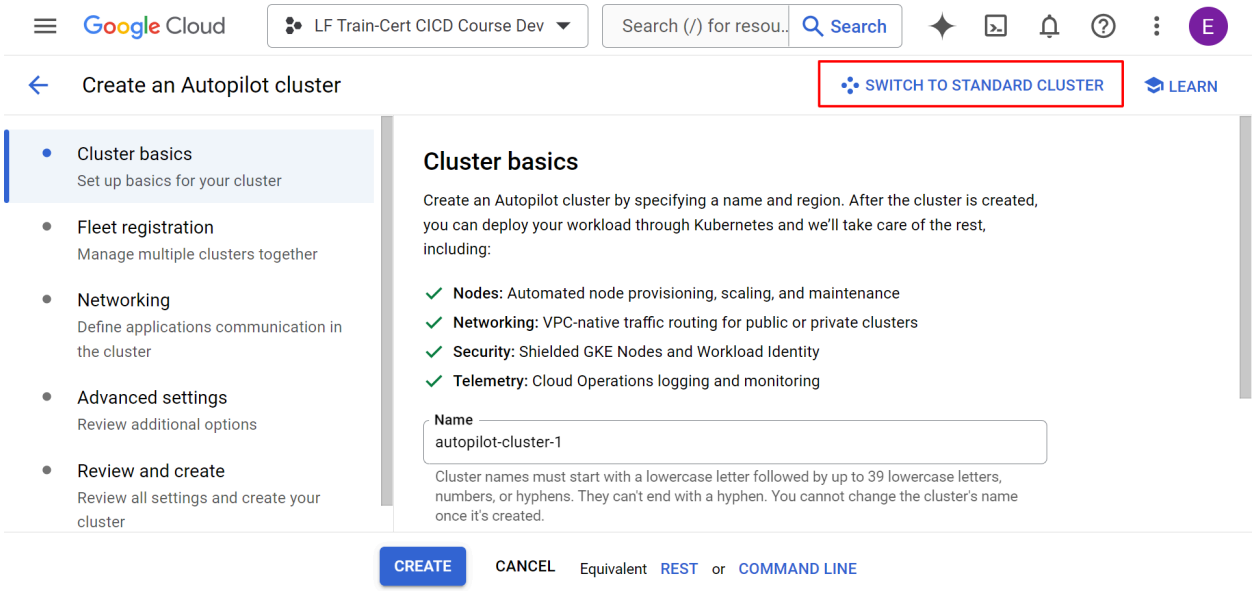
Be aware that if you are signing up for a Free Trial with some free credits, enabling a billing account does not automatically charge you. When you run out of free credits, you will be given some time to allow Google Cloud to charge your credit card. Your resources may be deleted if you run out of free credits and do not allow Google Cloud to charge your credit card.

Once you have completed these steps, go to **Google Cloud Console**, select **Kubernetes Engine > Clusters** and you will arrive at the following page, ready to launch a cluster.

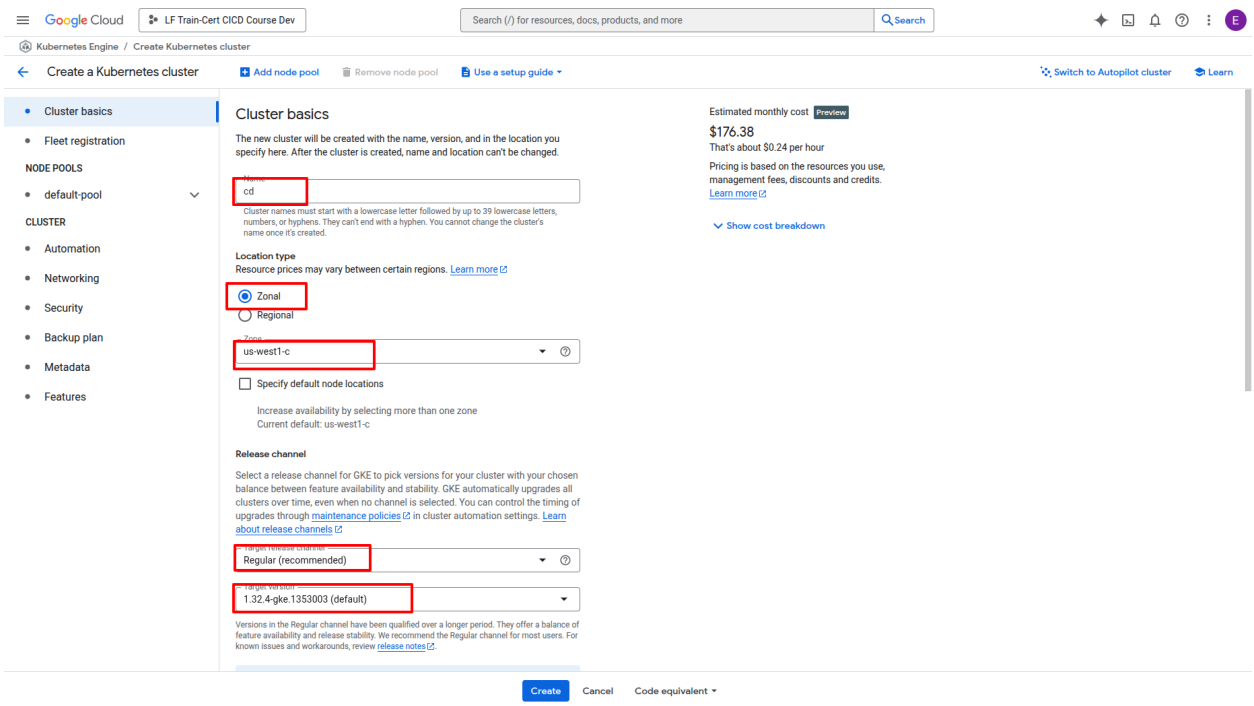




Click on **Create Cluster**, choose **Standard.**



This opens up a cluster configuration page similar to below. Provide the name for the cluster, e.g. **cd**, and select **Regular Channel** for control plane version. Do note, the actual version that you see may differ from what is shown in the screenshots.



Click on **Create** and wait for the cluster to be ready.

Connecting to Your Cluster

There are two ways to connect to your cluster. Either way will end up with you interacting with your cluster via a terminal in which you will run the commands given.

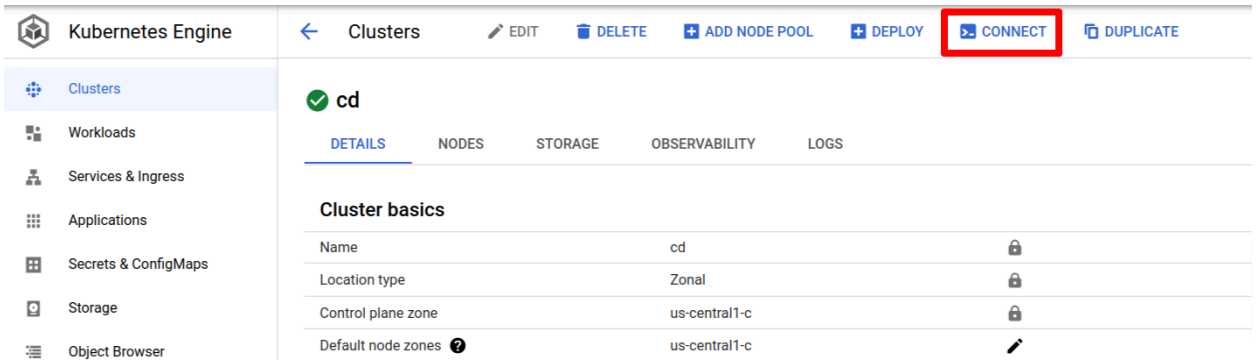
The first and easier way to connect to your cluster is via the **RUN IN CLOUD SHELL** option. The second is to manually connect to your cluster via your own machine.

We will go over both but it is suggested you use the easier method.

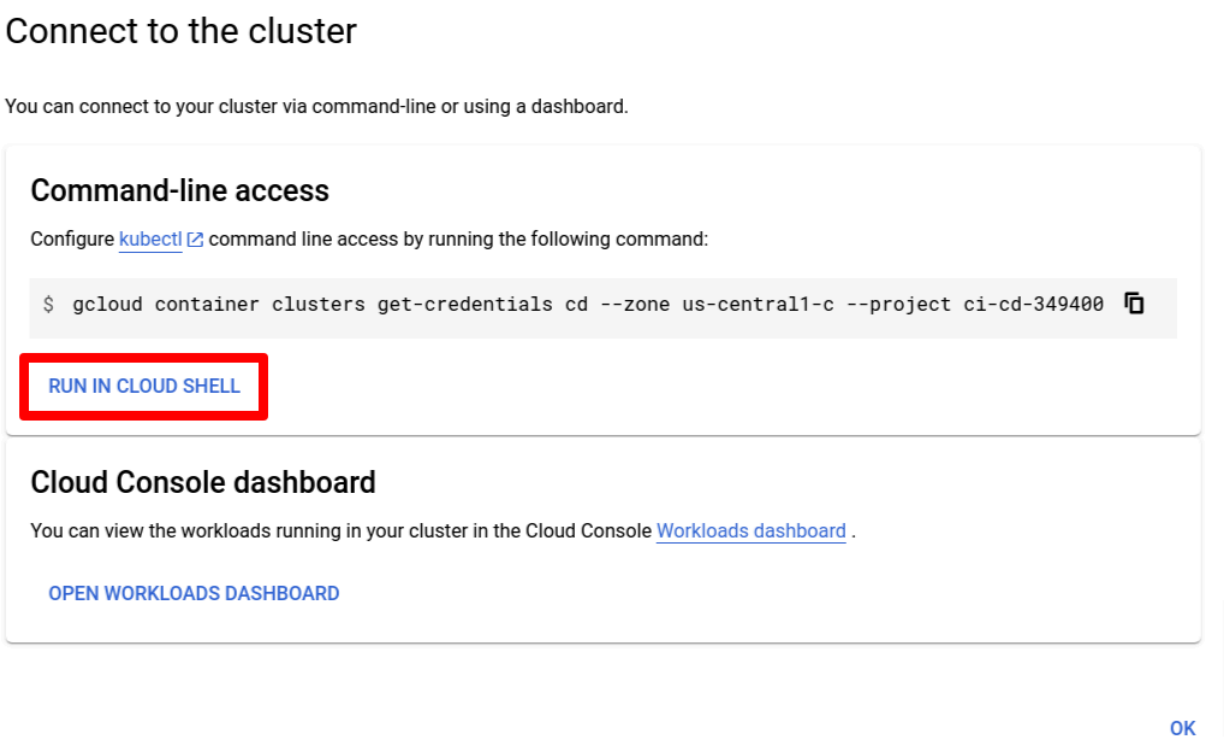
Connect to Your Cluster Via **RUN IN CLOUD SHELL**

Navigate to **Kubernetes Engine > Clusters > click on your cluster name**, as follows:

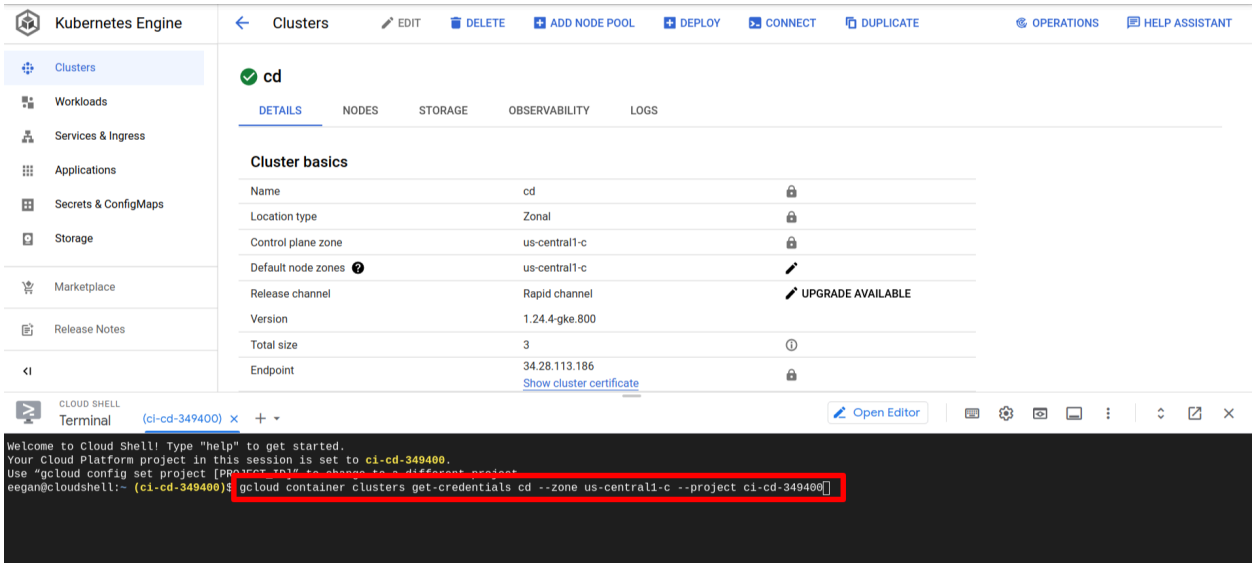
In the horizontal menu across the top of the screen you will see the **CONNECT** option. Click it:



A pop up window will appear. Click **RUN IN CLOUD SHELL**:



A terminal will appear with the **gcloud** command to connect to your cluster pre-populated.



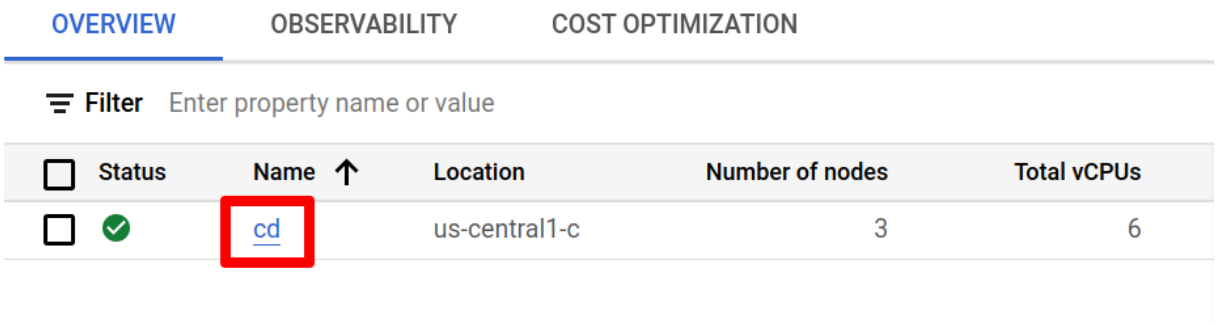
Press **Enter** and you will be connected to your cluster via a terminal.

Manual Connection to Your Cluster

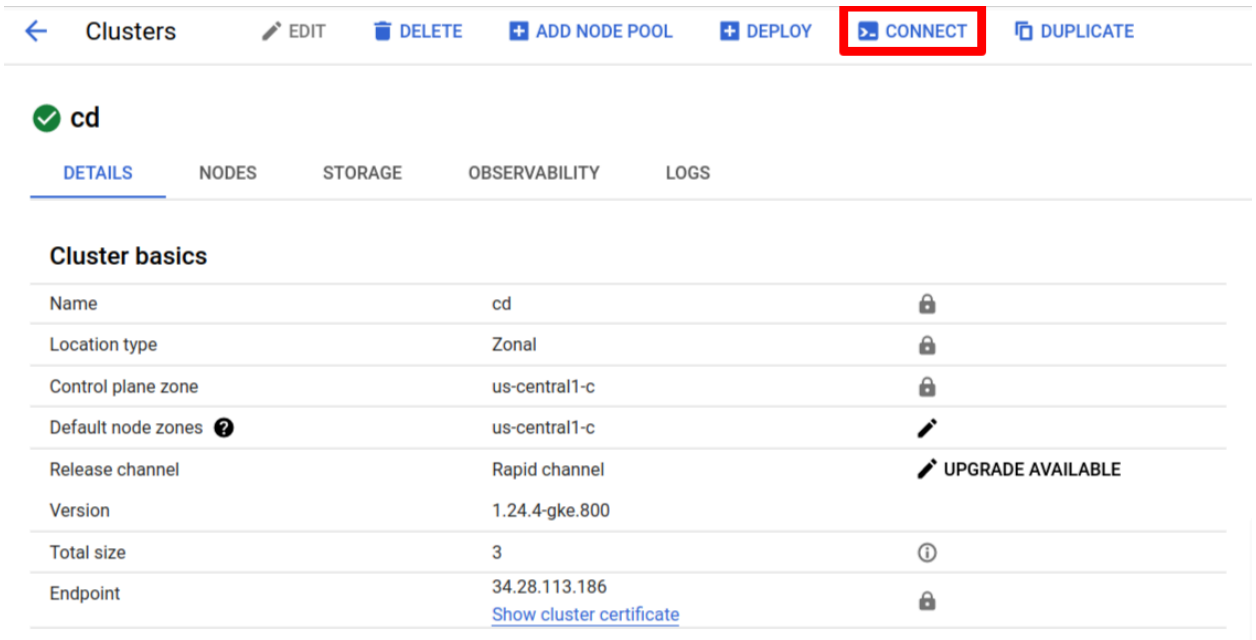
To connect to your cluster via your own machine, use the following:

- Read the Google SDK installation guide.
- Install Google SDK with interactive option.
- Install kubectl by referring to the documentation relevant to your OS.

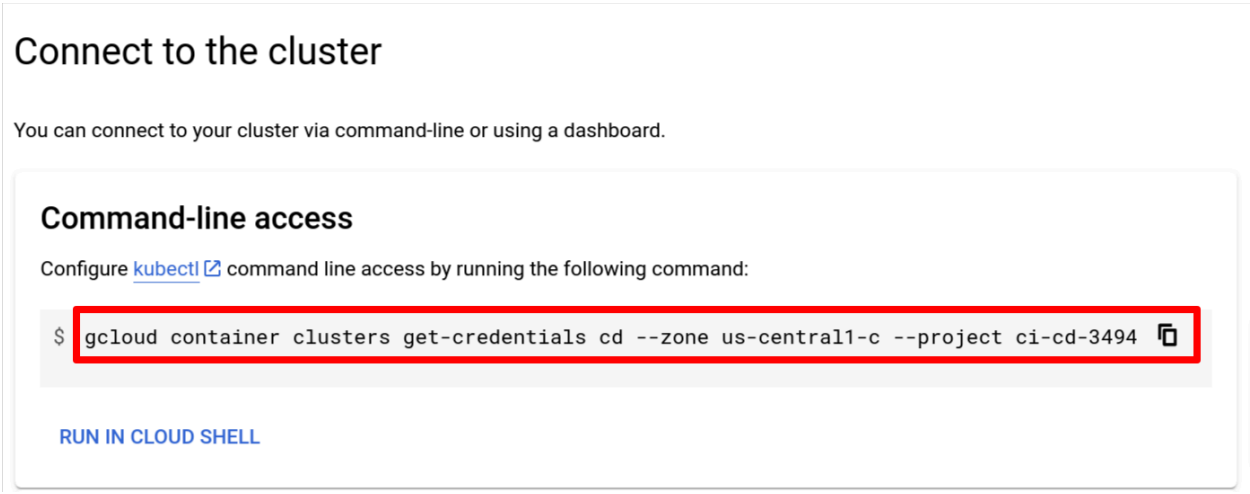
Navigate to **Kubernetes Engine > Clusters** and click on the name of your cluster.



Click on **CONNECT.** If you don't see it, you are likely zoomed in too far in your browser settings and it will be under the vertical three-dot menu on the right.



A popup window should appear. Copy the **`Connect to the cluster`** command and run it on the host where you have installed **`kubectl`**.



Verify **`kubectl`** configuration using the following commands:

```
kubectl version -o yaml
```

```
clientVersion:
  buildDate: "2025-05-15T20:09:34Z"
  compiler: gc
  gitCommit: 4cb5f0764b8d5f425645c6f433394fede34a8a26
  gitTreeState: clean
  gitVersion: v1.32.4-dispatcher
  goVersion: go1.23.8
  major: "1"
  minor: 32+
  platform: linux/amd64
kustomizeVersion: v5.5.0
serverVersion:
  buildDate: "2025-05-19T04:19:46Z"
  compiler: gc
  gitCommit: d05b573072d7732178c3b9a376809c1d945f669f
  gitTreeState: clean
  gitVersion: v1.32.4-gke.1353003
  goVersion: go1.23.8 X:boringcrypto
  major: "1"
  minor: "32"
  platform: linux/amd64
```

```
kubectl get nodes
```

When you run **`kubectl get nodes`** you should see three nodes listed with **Ready** status.

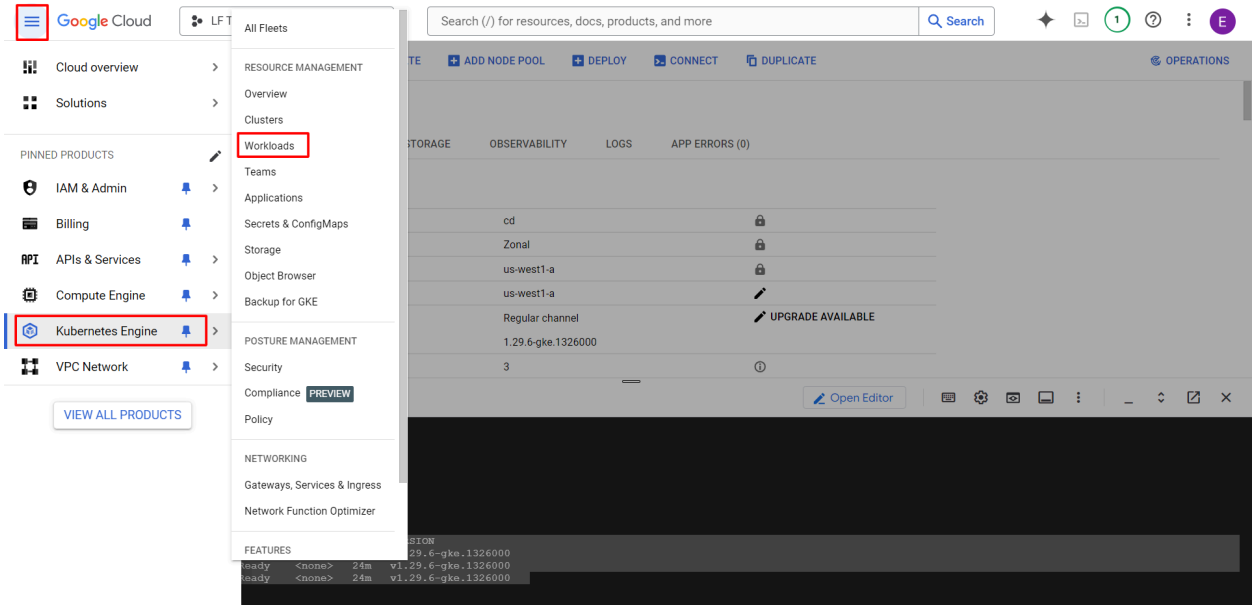
Sample output:

```
NAME                                   STATUS   ROLES    AGE   VERSION
gke-cd-default-pool-4c6b87d8-39cg      Ready    <none>   26m   v1.32.4-gke.1353003
gke-cd-default-pool-4c6b87d8-9rbn      Ready    <none>   26m   v1.32.4-gke.1353003
gke-cd-default-pool-4c6b87d8-pwg0      Ready    <none>   26m   v1.32.4-gke.1353003
```

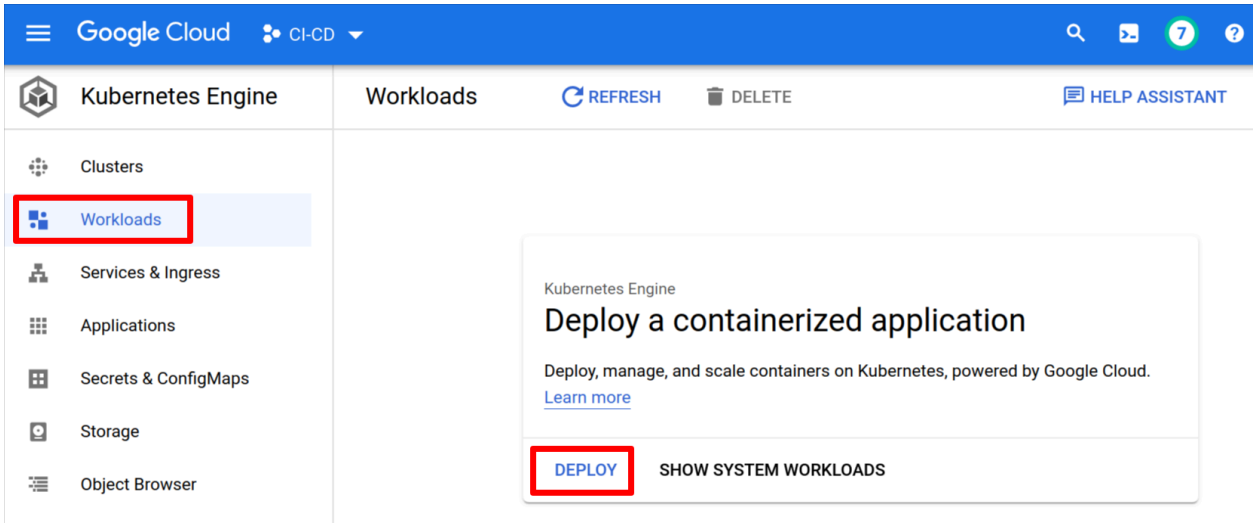
This validates that the cluster is ready and operational.

Deploy the Frontend Vote App with Kubernetes

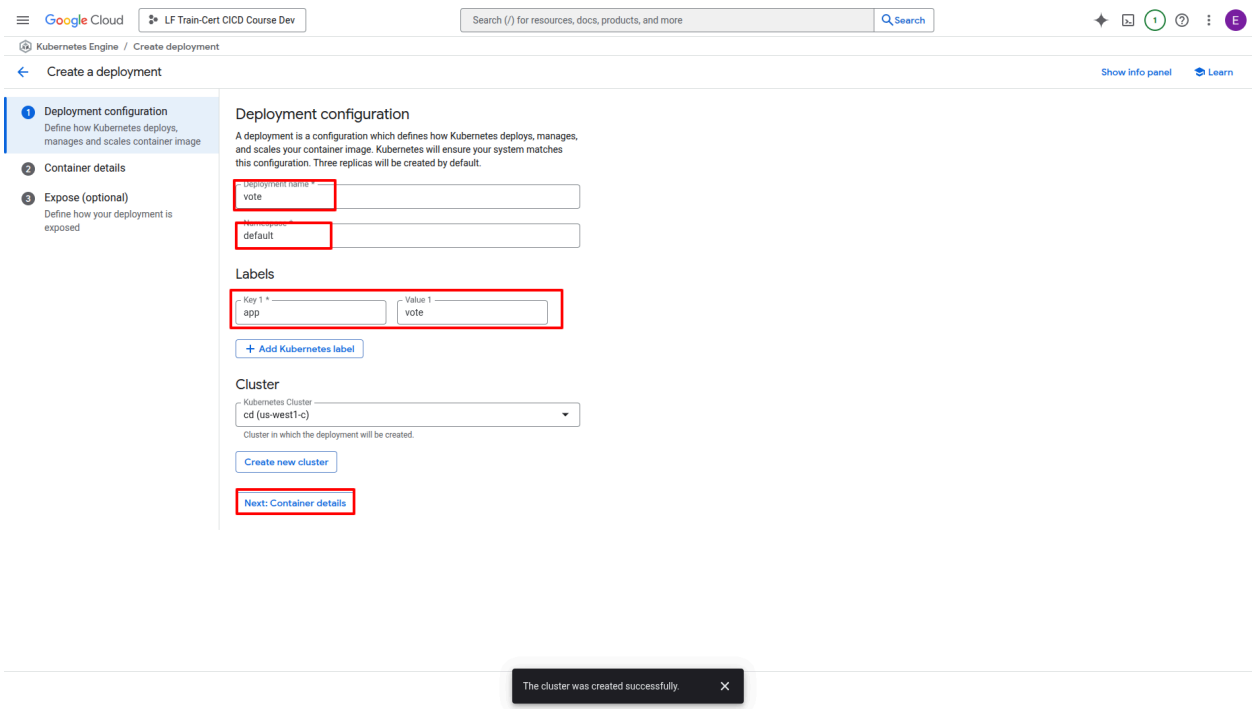
Navigate to Google Kubernetes Engine's **Workloads:**



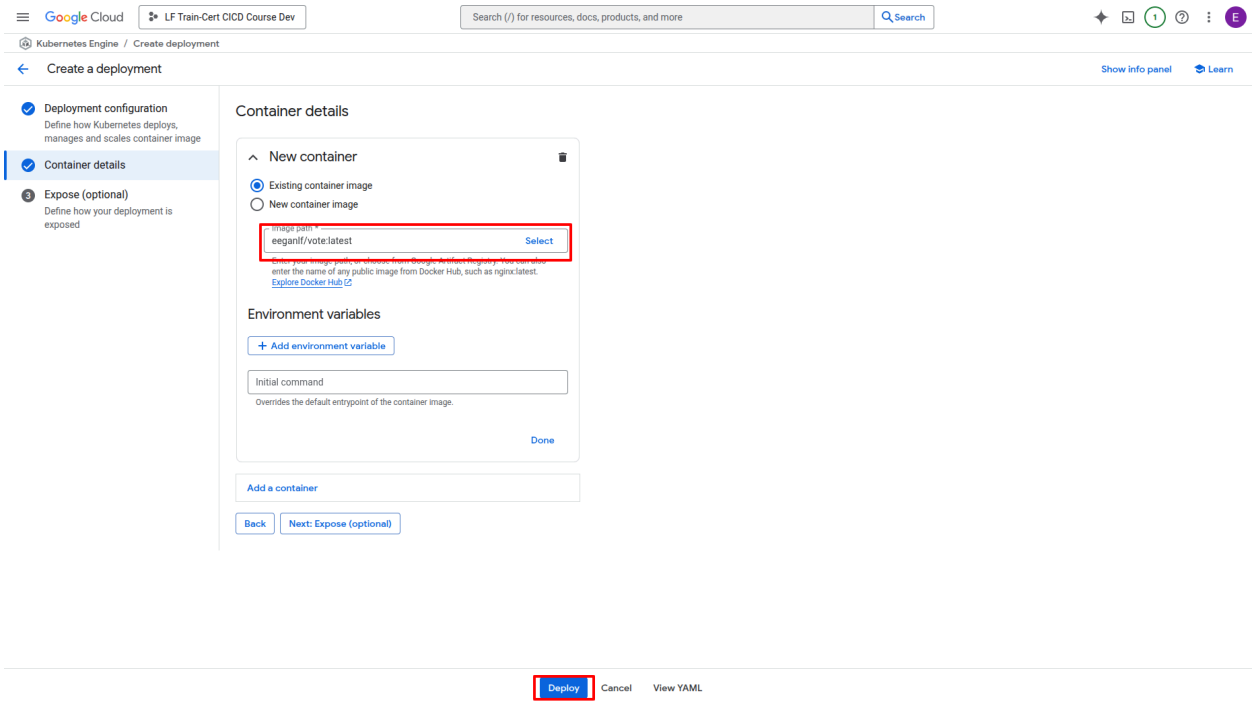
Click **Create Deployment**.



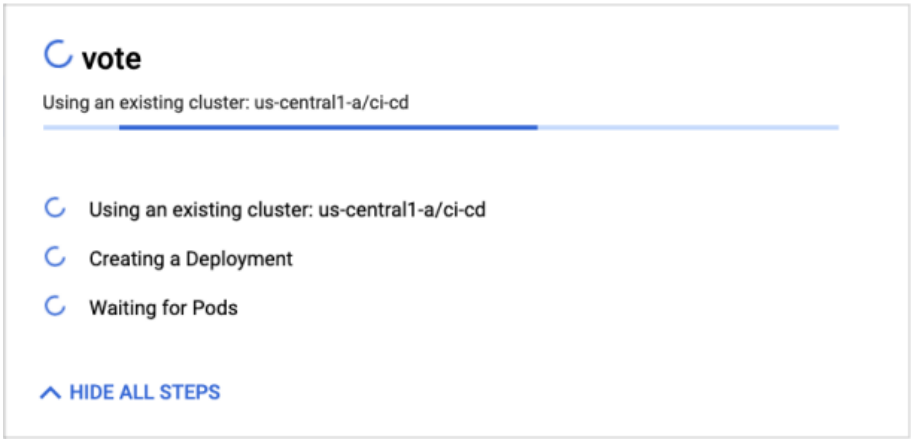
Provide the configurations to deploy the frontend `vote` app as follows and click **Next** to access the container details page.

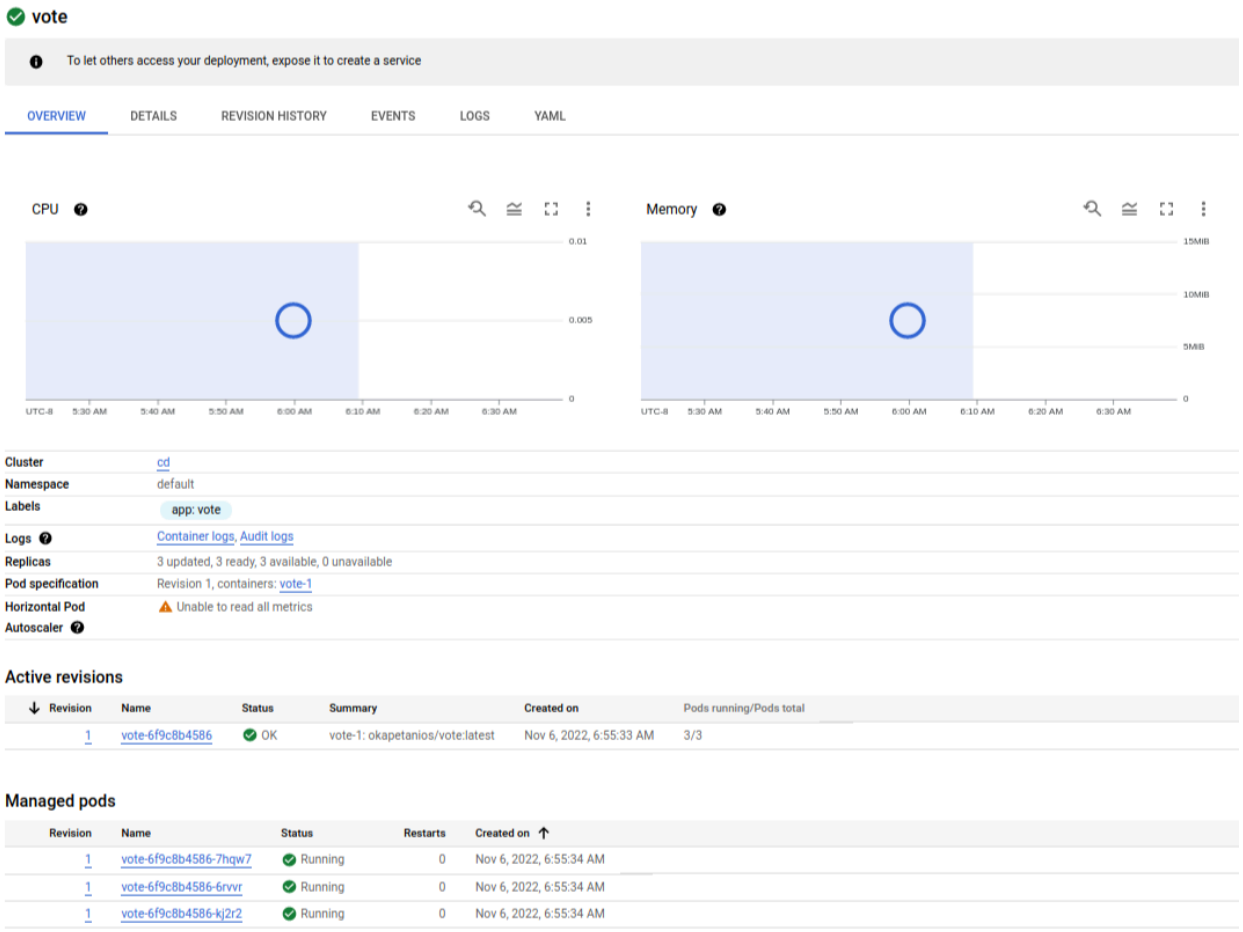


We will use our existing container image: **`DockerHubUserID/vote`**. NOTE: Replace the image with your actual image tag.



Click **Deploy**.





Your app is now deployed on the cluster.

Pod Operations

From the host where **`kubectl`** is configured, you can explore pod operations by running the following commands:

```
kubectl get pods
```

```
kubectl get pods -o wide
```

***NOTE**: Replace **`vote-xxxx`** with the actual pod names displayed under **`kubectl get pods`**.*

```
kubectl describe pods vote-xxxx
```

```
kubectl logs vote-xxxx
```

```
kubectl exec vote-xxxx -- ps
```

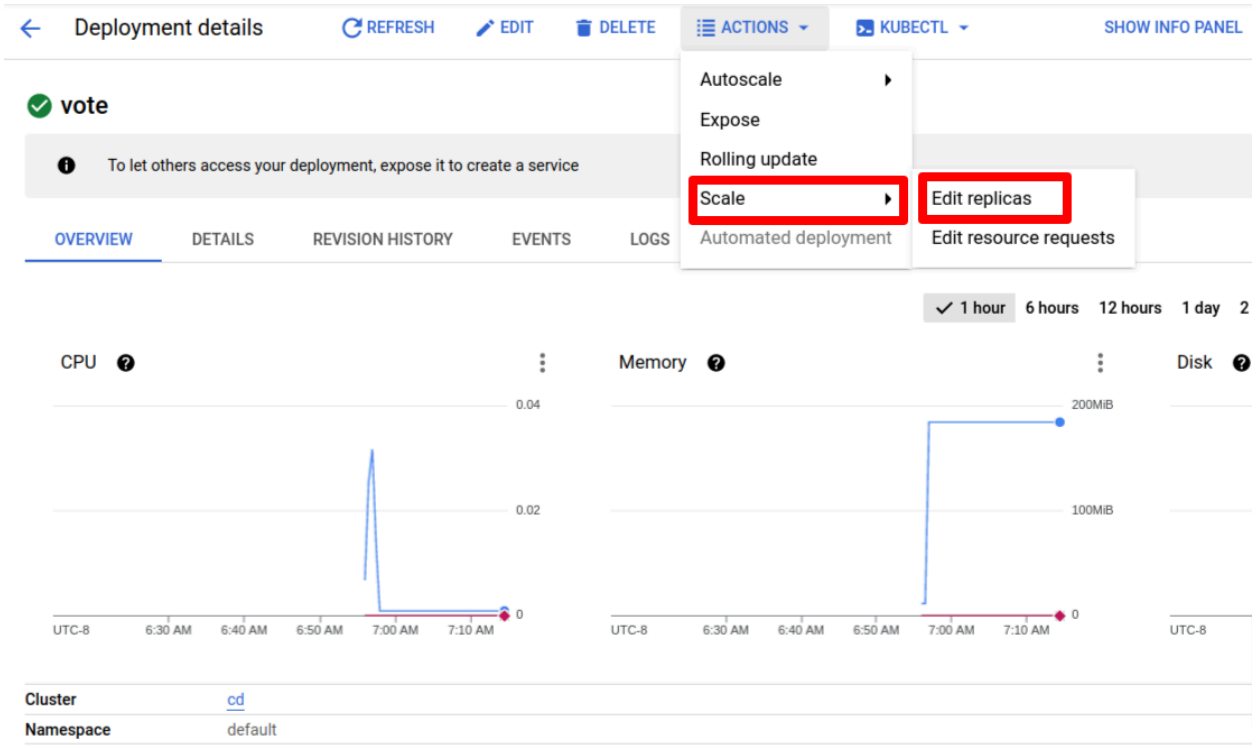
```
kubectl exec -it vote-xxxx -- sh
```

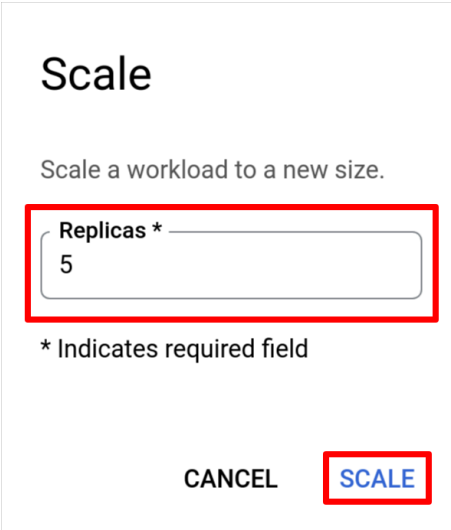
Use **CTRL + d** to exit from the container's shell.

Scalability

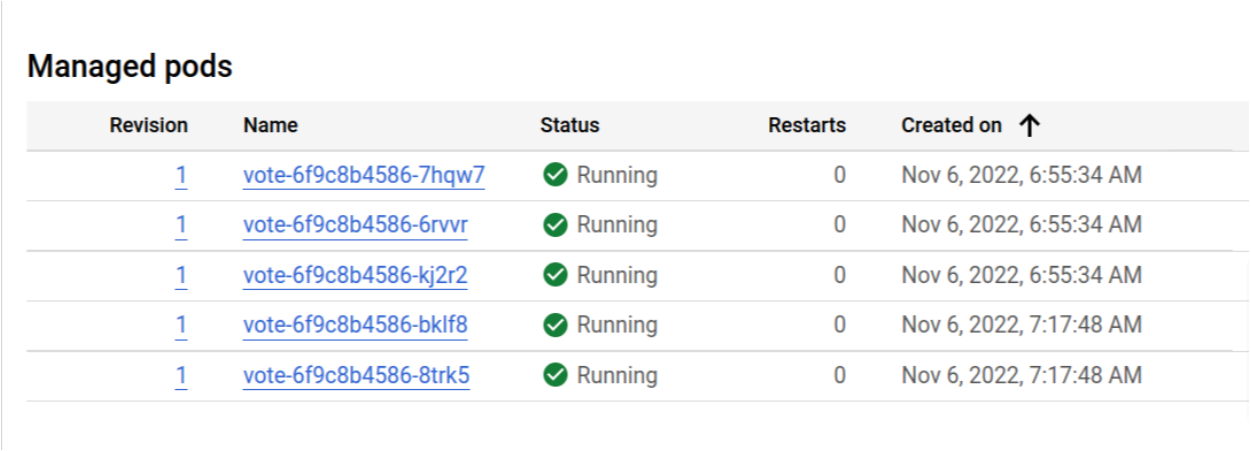
Scaling Manually

Click the **ACTIONS** menu and select **Scale > Edit replicas.**





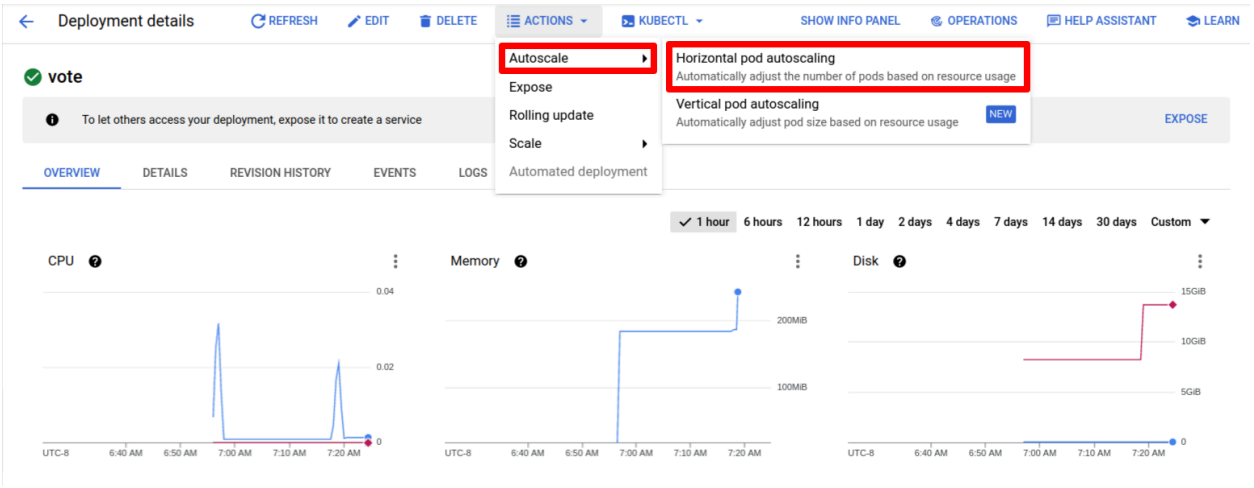
Under the **Managed pods** section, you will now see that 5 pods have been deployed.



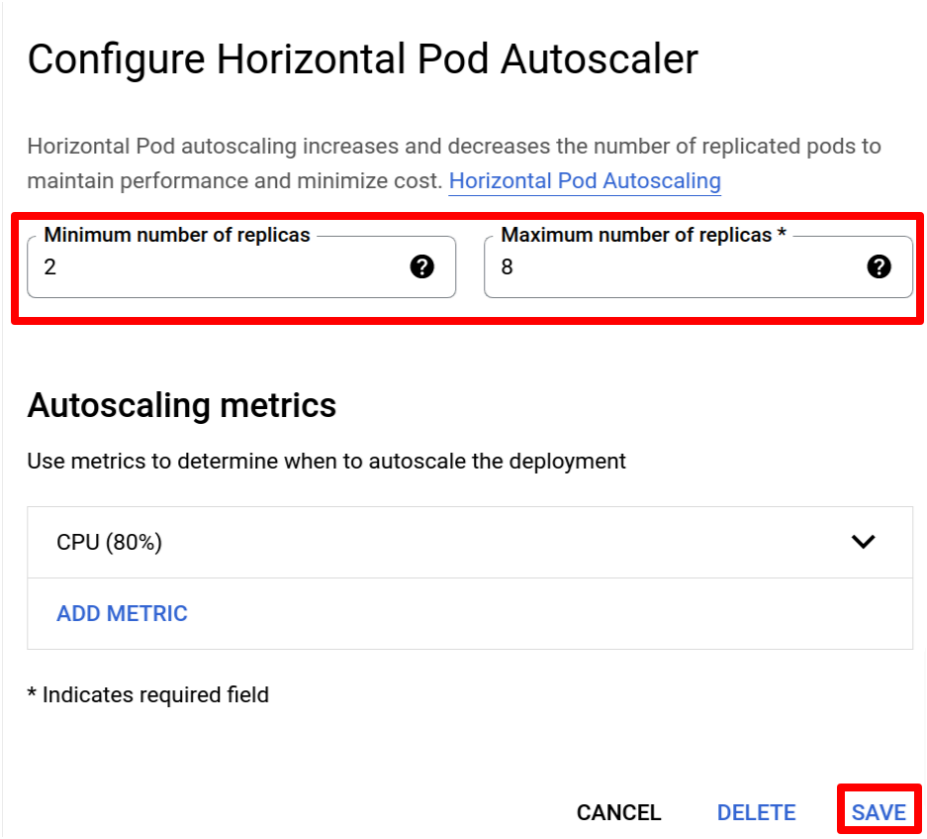
You have manually scaled your application using Kubernetes with Google's Kubernetes Engine.

Autoscaling

You will now configure Kubernetes to handle the scaling for your cluster automatically. Once again, navigate to **ACTIONS**. This time select **Autoscale > Horizontal pod autoscaling** from the dropdown, as follows:



Give your deployment a minimum of 2 replicas and a maximum of 8, as follows:



You will now test that your autoscaling works by attempting to delete pods.

Availability

Try deleting a few pods after listing them and observe what happens. You should see new pods created automatically.

```
$ kubectl get pods

NAME                    READY   STATUS    RESTARTS   AGE
vote-799cf486bf-ctvww   1/1     Running   0          4s
vote-799cf486bf-jmr5b   1/1     Running   0          8s
vote-799cf486bf-jnwbs   1/1     Running   0          8s
vote-799cf486bf-p5wzc   1/1     Running   0          8s
```

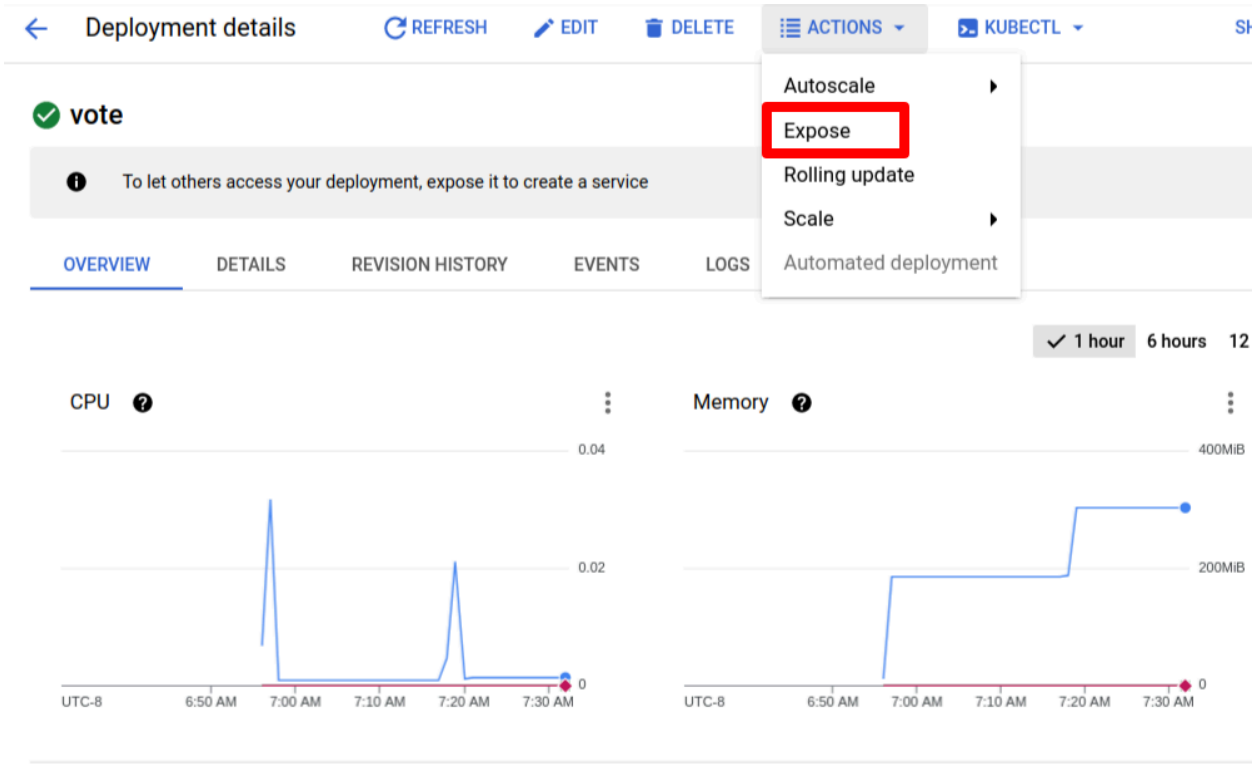
***NOTE**: Replace the following **vote-xxxx-xxxx** pod names with your own.*

```
$ kubectl delete pods vote-799cf486bf-jnwbs vote-799cf486bf-p5wzc
pod "vote-799cf486bf-jnwbs" deleted
pod "vote-799cf486bf-p5wzc" deleted

$ kubectl get pods

NAME                    READY   STATUS    RESTARTS   AGE
vote-799cf486bf-bw4bf   1/1     Running   0          14s
vote-799cf486bf-ctvww   1/1     Running   0          34s
vote-799cf486bf-d7dzq   1/1     Running   0          14s
vote-799cf486bf-jmr5b   1/1     Running   0          38s
```

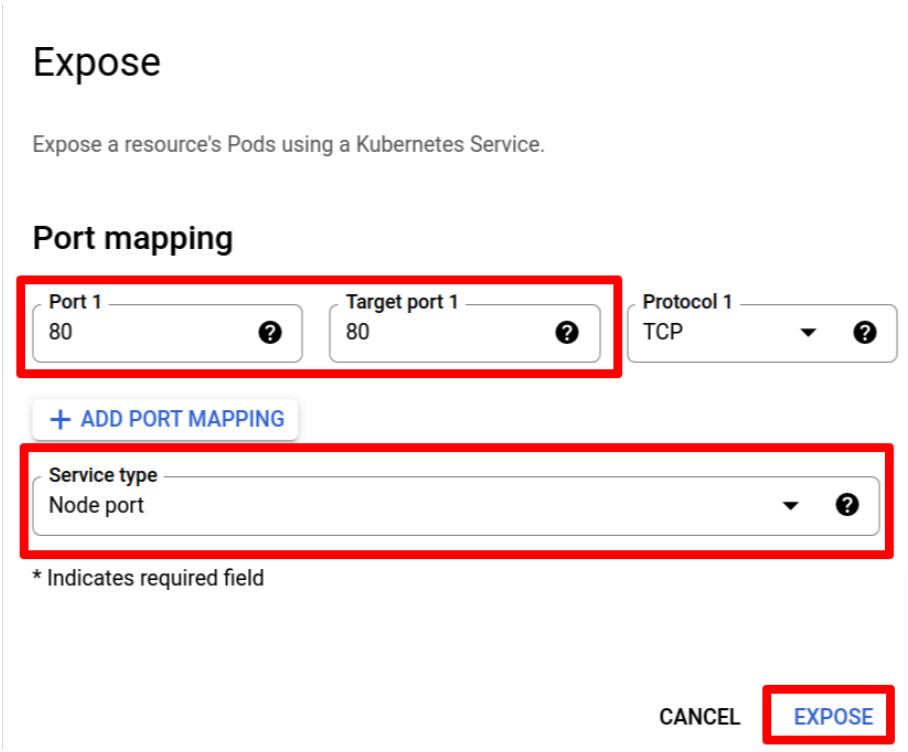
Kubernetes has created new pods to replace the ones you deleted. Kubernetes always maintains the desired scale that you provide and constantly monitors and takes action if the desired count changes. This is an example of availability, fault tolerance, and resilience.

Publishing and Load Balancing with Services

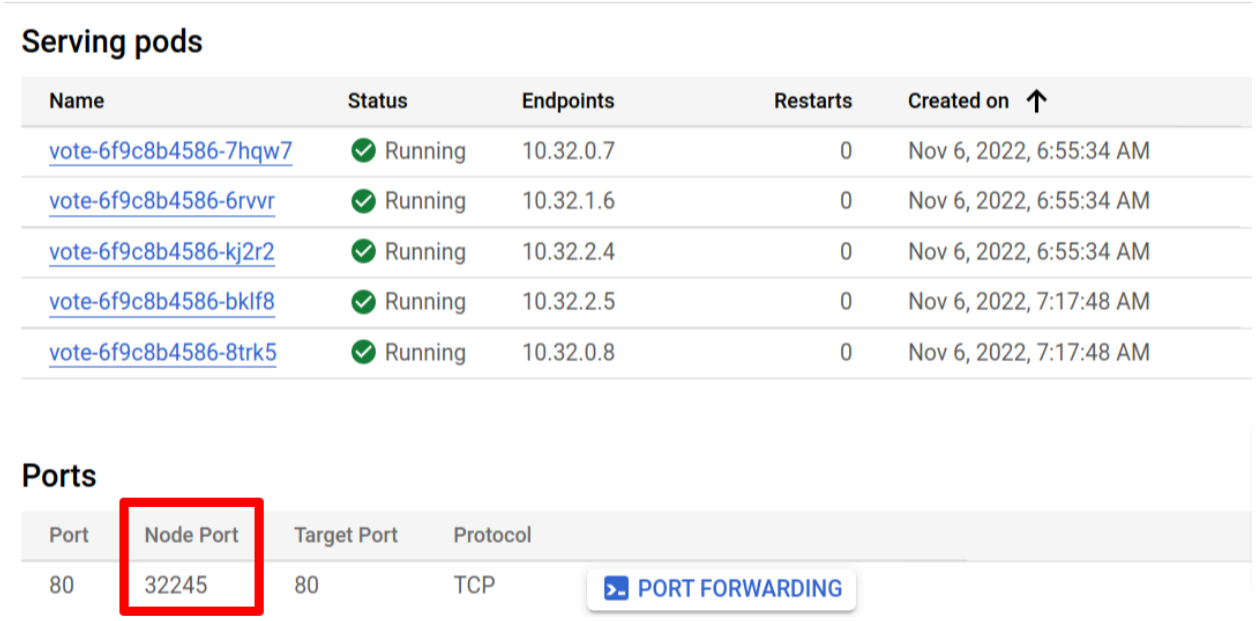
Browse to **Workloads > vote > Actions** and then select **Expose**.



Provide values for “Port” and “Target Port” as 80 and then choose **NodePort** from the **Service type** dropdown. This is an important step in order to access this application from outside the cluster.



Once created, browse to **Kubernetes Engine > Gateways, Services & Ingress > Services > vote-xxxx.** Scroll to the **Ports** section and find the NodePort associated with it.

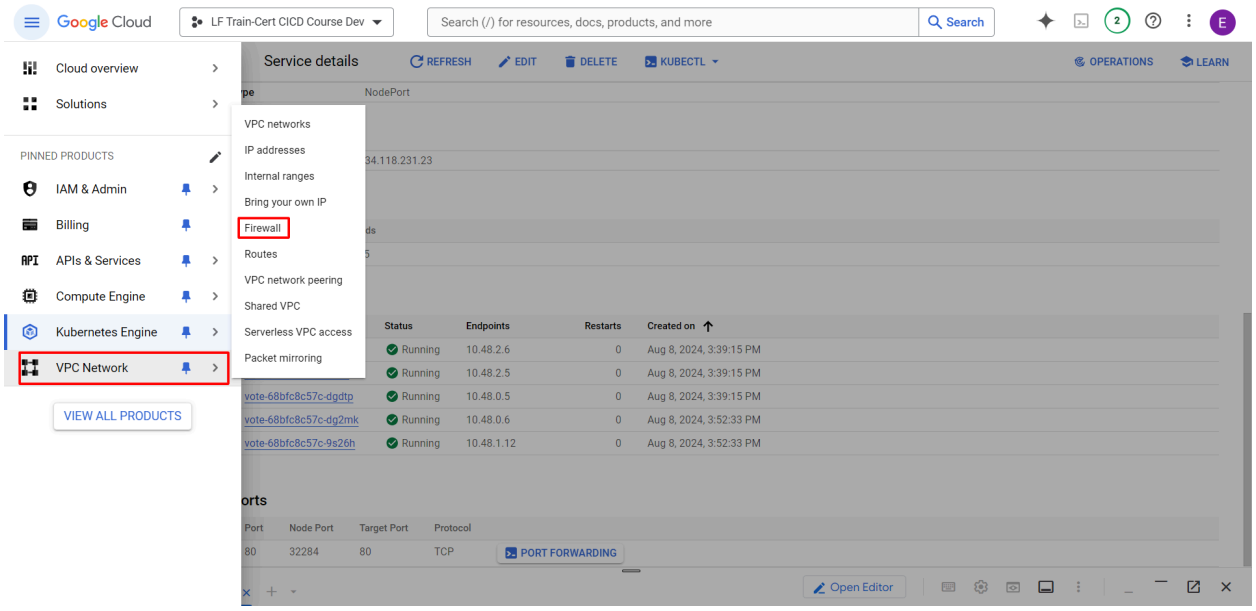


You will need to know this later.

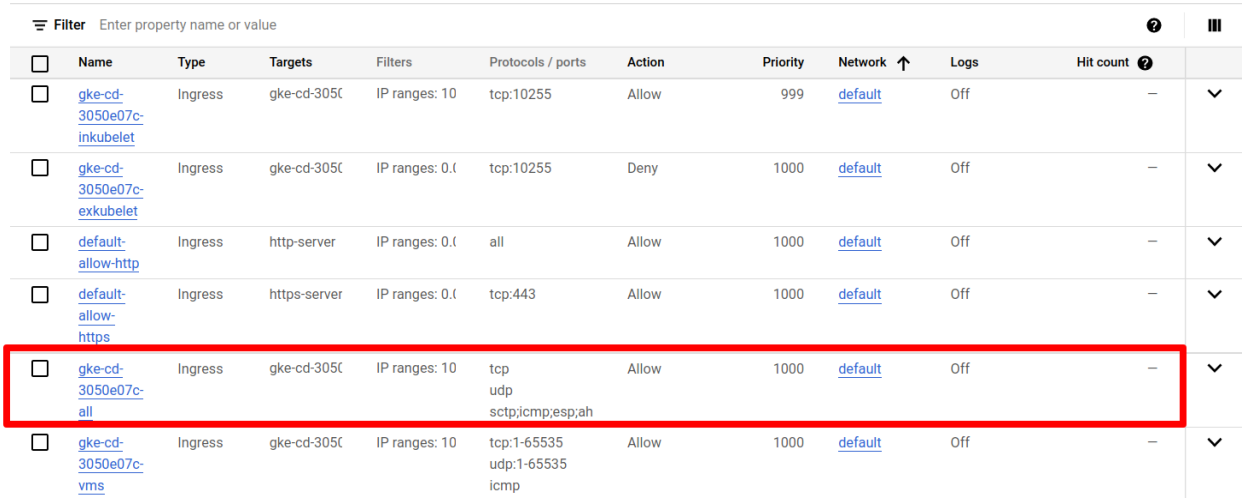
Opening Firewall Rules

You may have already performed the following steps at the time of creating the cluster. If not, open the firewall rules, as follows, in order for you to be able to access the services from outside the cluster (e.g. using a browser on your workstation, which is outside the GKE cluster).

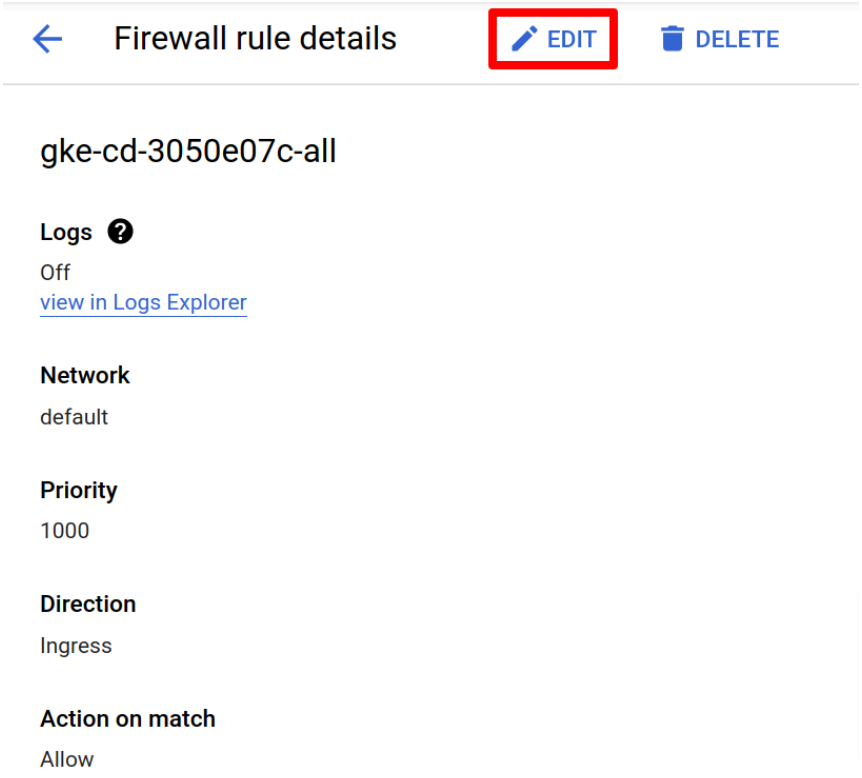
Navigate to the main cloud console menu and **VPC network > Firewall**:



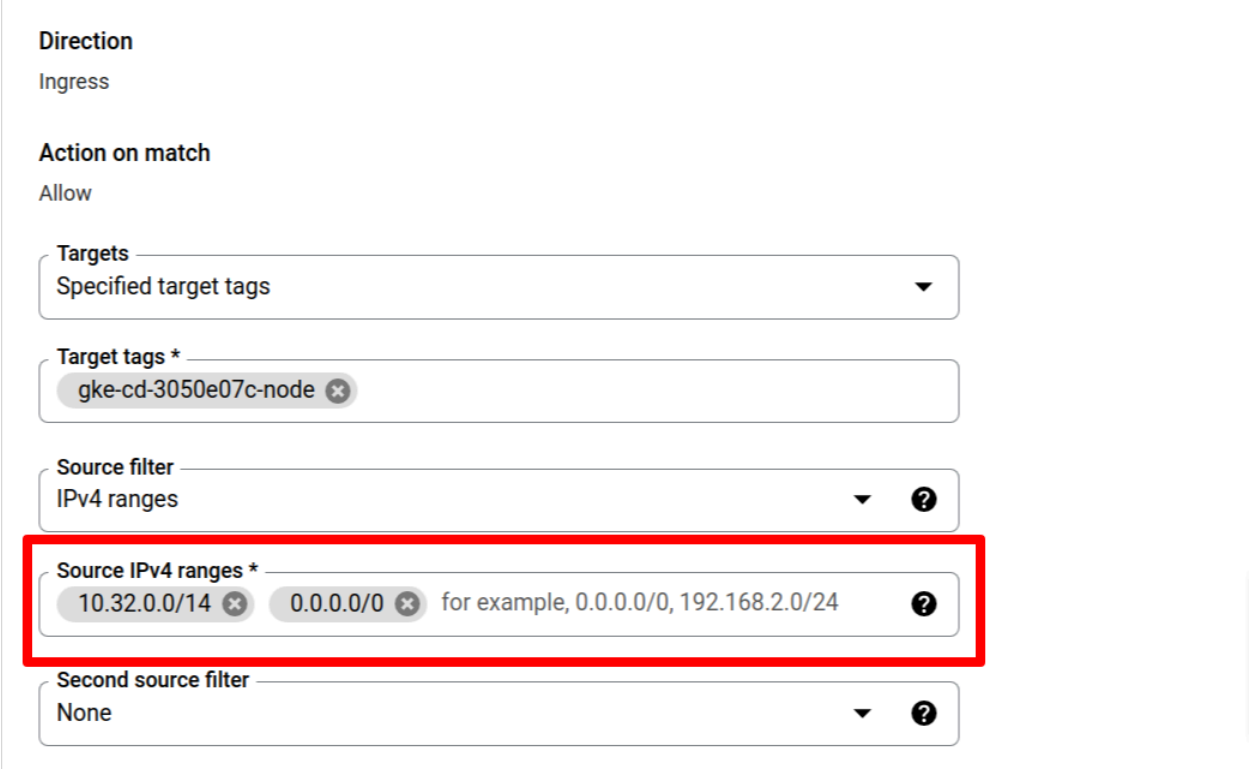
Scroll to the rule that ends in `-all` and click on it:



Click **EDIT**:



Scroll to **Source IPv4 ranges** and enter `0.0.0.0/0`:



Click **Save** at the bottom of the screen.

Find the external IP address of the nodes participating in the Kubernetes cluster.

Alternately, you can find the external IPs of the nodes by using the following command:

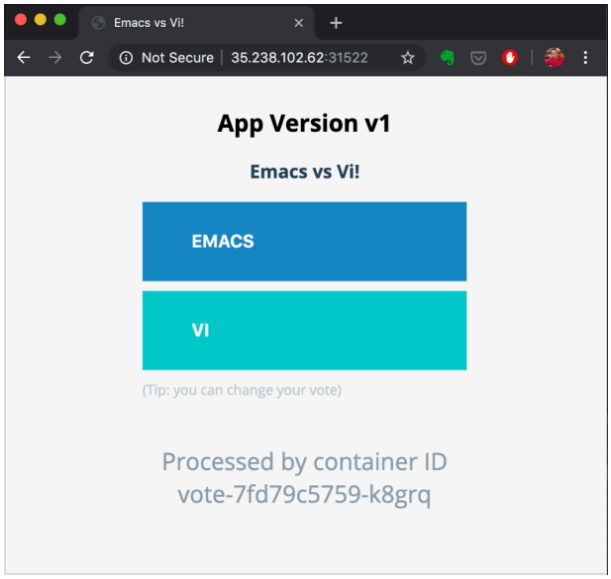
```
kubectl get nodes -o wide
```

Sample output:

```
NAME                                     STATUS   ROLES    AGE   VERSION
INTERNAL-IP   EXTERNAL-IP      OS-IMAGE
KERNEL-VERSION   CONTAINER-RUNTIME

gke-cd-default-pool-4c6b87d8-39cg   Ready    <none>   19h
v1.32.4-gke.1353003   10.138.0.38   34.53.78.232     Container-Optimized OS
from Google   6.6.72+          containerd://1.7.24

gke-cd-default-pool-4c6b87d8-9rbn   Ready    <none>   19h
v1.32.4-gke.1353003   10.138.0.37   34.168.221.251   Container-Optimized OS
```

```
from Google   6.6.72+          containerd://1.7.24

gke-cd-default-pool-4c6b87d8-pwg0   Ready    <none>   19h
v1.32.4-gke.1353003   10.138.0.39   35.185.198.94    Container-Optimized OS
from Google   6.6.72+          containerd://1.7.24
```

Use any of the external IPs and load the application by using NodePort as **`http://IPADDRESS:NODEPORT`**. For example:

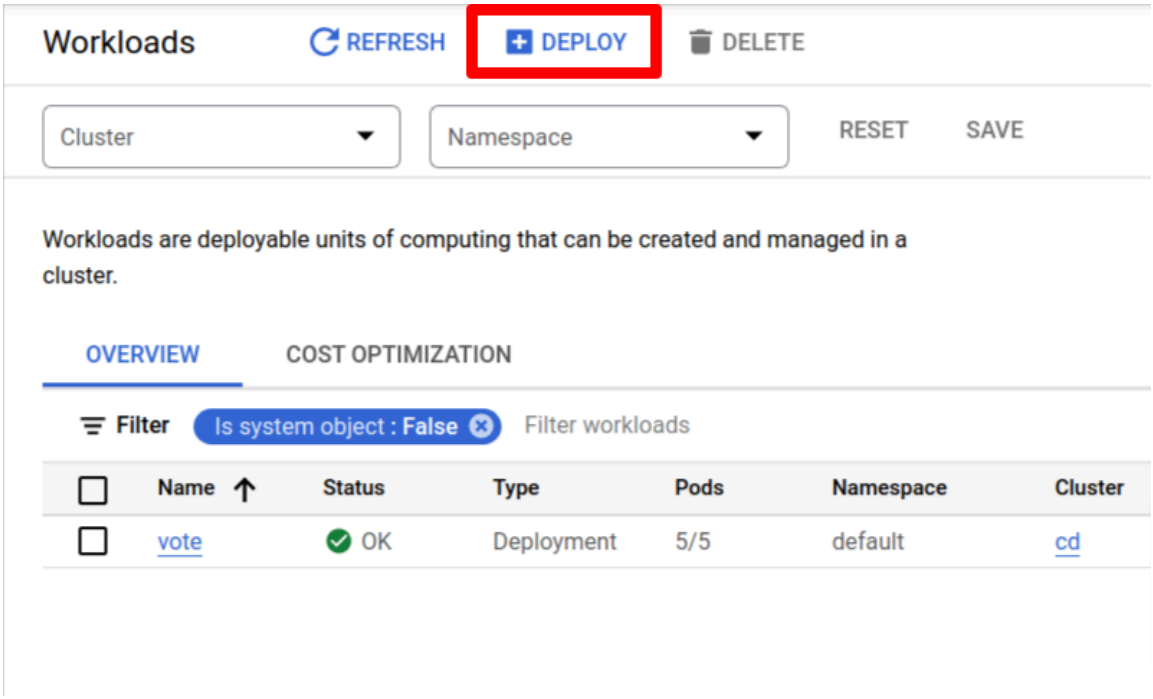


Try reloading the URL a few times and observe the container ID. Do you see the container IDs changing? If yes, the load balancing is in place.

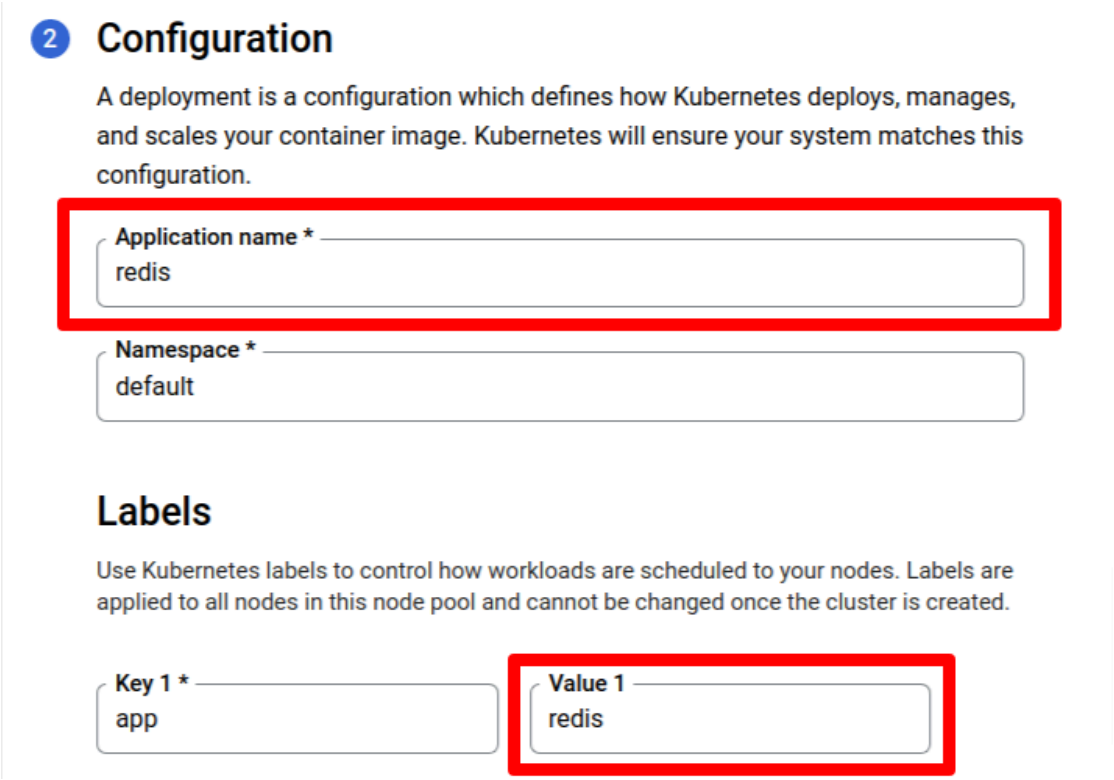
Try clicking an option. You will notice that the app crashes. This is because the **`redis`** backend is not set up. This is what you will do in the next section.

Service Discovery

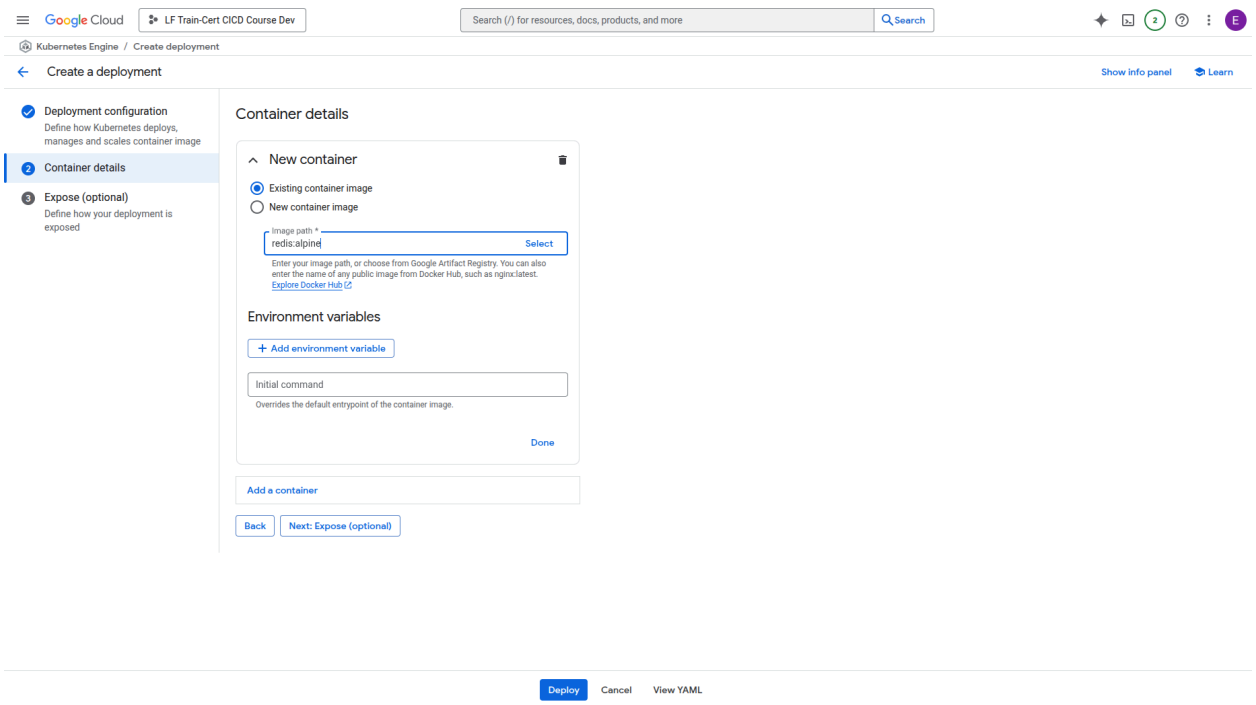
To launch the **`redis`** backend microservice go to **Kubernetes Engine > Workloads** and select the **Deploy** option.



Enter the **Application name** and **Value 1** as `redis`.



Provide the image `redis:alpine` and click on **Deploy**.

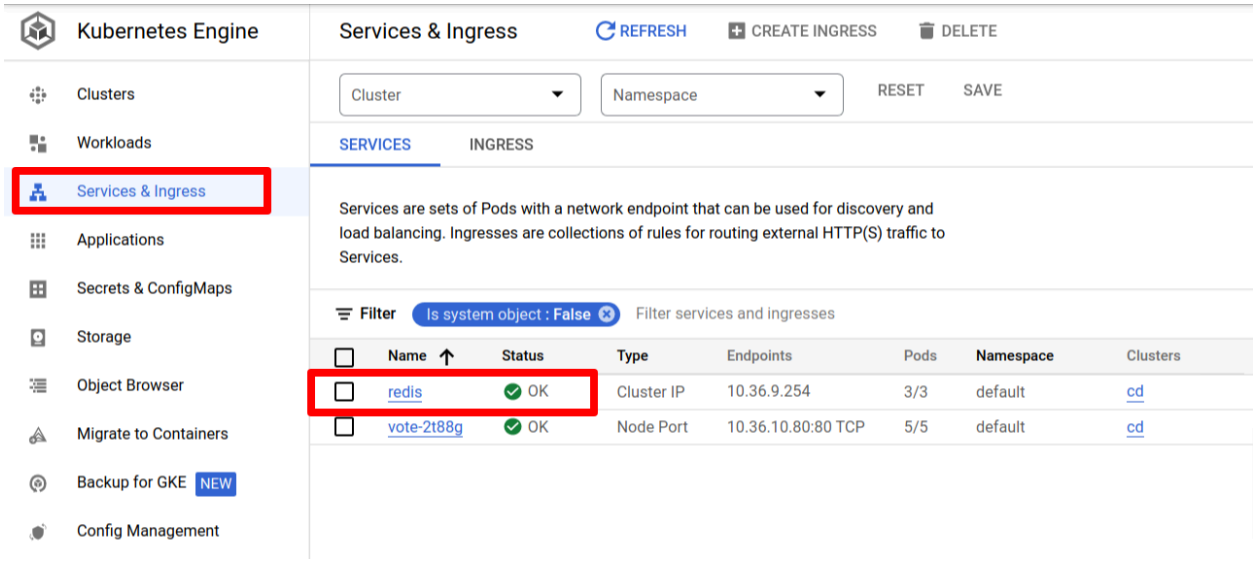


Wait for the **`redis`** deployment to be ready.

Enter the following command into your terminal to expose the **`redis`** application as a service:

```
$ kubectl expose deployment redis --port=6379 --name=redis
service/redis exposed
```

Navigate to **Kubernetes Engine > Services and Ingress**. You will notice the `redis` service is listed:



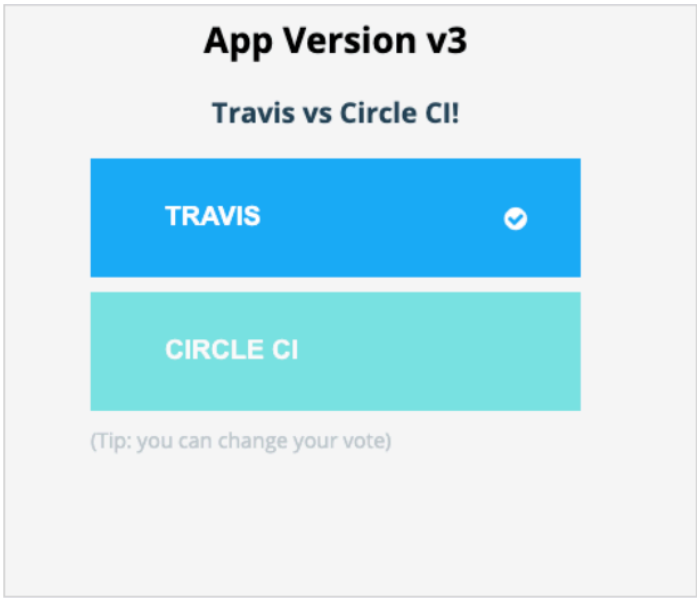
This means you can submit a vote on the vote application and it won't crash.

Run:

```
$ kubectl get node -o wide
```

The output will show your nodes. Under the `EXTERNAL-IP` column you will find the public IP's associated with each of your nodes. You can navigate to any of these IP's with the frontend port, which is found at **Kubernetes Engine > Services & Ingress > vote-xxxx > Ports > Node Port**. Enter the following into your web browser to see the frontend and click to vote:

`NODEIPADDRESS:NODEPORT`



As soon as you submit the vote, you should see a tick, which validates the communication between the frontend vote and the backend redis applications.

Summary

In this lab, we set up an account on Google Cloud. We installed the **`kubectl`** command line utility and set it up to interact with our cluster on Google Cloud. We then deployed the voting application to a Kubernetes Cluster on Google Cloud so that we can visit the app from any browser and submit a vote.

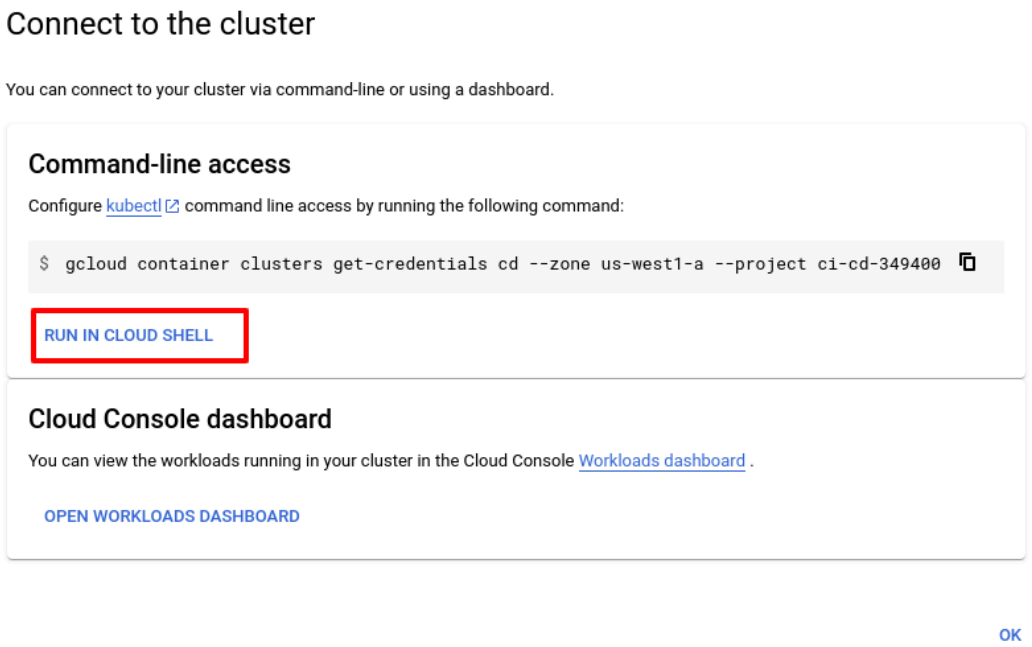
Lab 11. Continuous Deployment with Argo CD

By the end of this lab exercise, you should be able to:

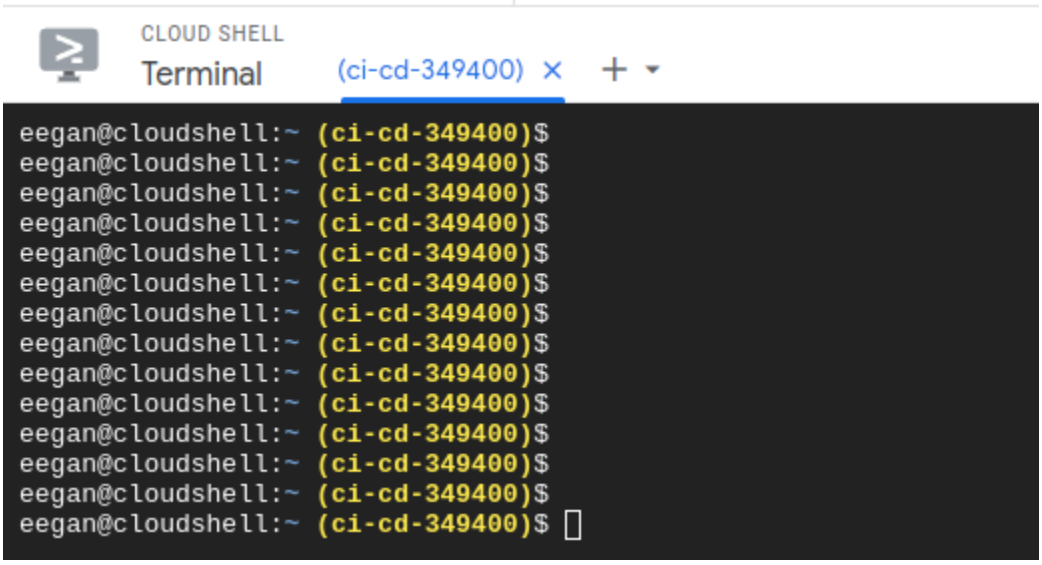
- Implement ArgoCD on a cluster in the cloud
- Set up an automated deployment pipeline with Jenkins and Argo CD

Connect to the Cluster

In order to install ArgoCD onto the cluster, we need to connect to our cluster with the **CLOUD SHELL** option.



This will open a terminal at the bottom of your browser:



You will type the commands to deploy ArgoCD into this terminal.

Deploy ArgoCD to the Cluster

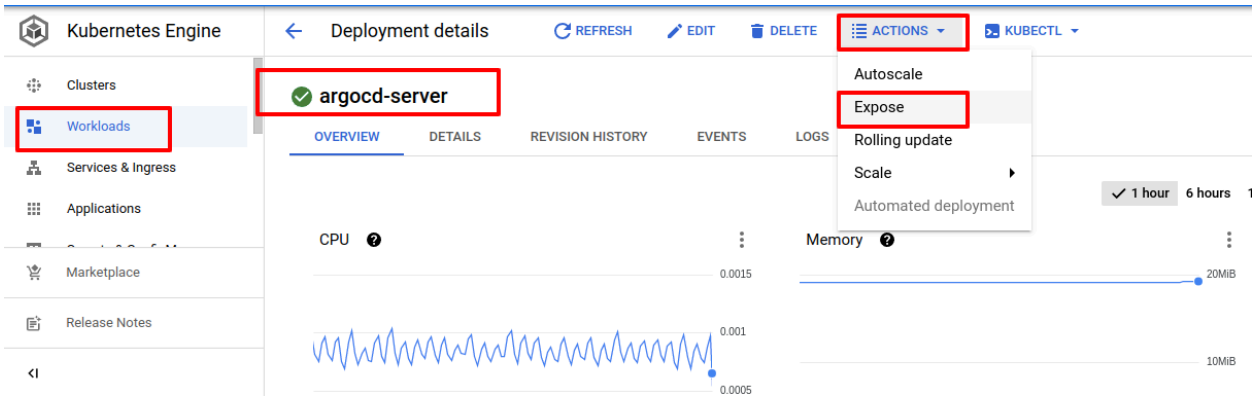
First, create a namespace for **`argocd`** to separate it from the rest of the services running in the cluster:

```
$ kubectl create namespace argocd
namespace/argocd created

kubectl get namespace
NAME              STATUS   AGE
argocd            Active   7s
default           Active   13d
kube-node-lease   Active   13d
kube-public       Active   13d
kube-system       Active   13d
```

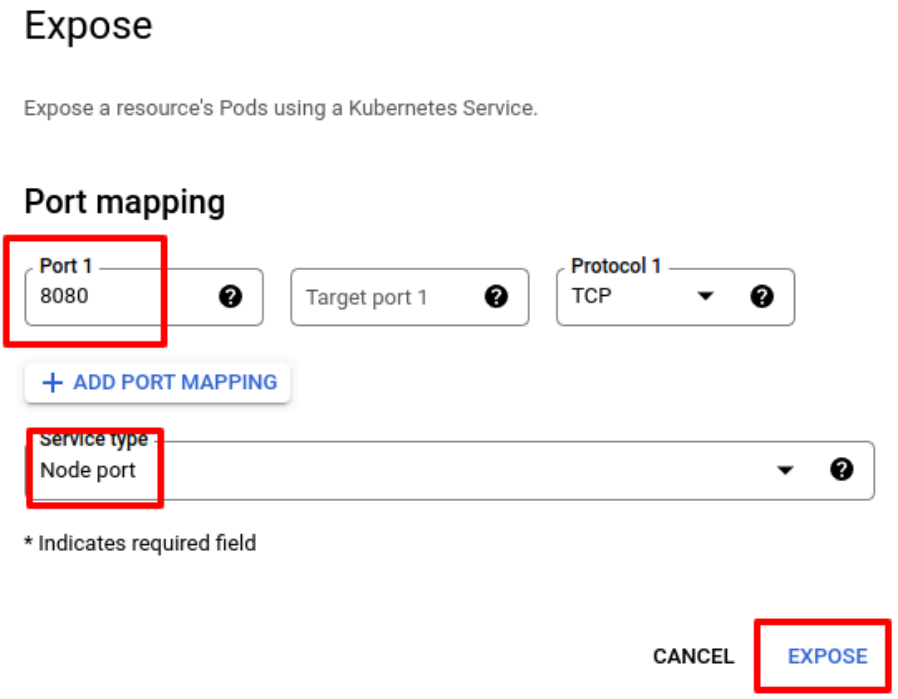
Then apply the installation yaml file from Argo Project's GitHub repository:

```
$ kubectl apply -n argocd -f
https://raw.githubusercontent.com/argoproj/argo-cd/stable/manifests/in
stall.yaml

$ kubectl get svc -n argocd
```

Note that the ports that **`argocd-server`** is using are 443 and 80. We need to expose these ports on a service. Under **Workloads > argocd-server** click **Actions** and choose **Expose**.

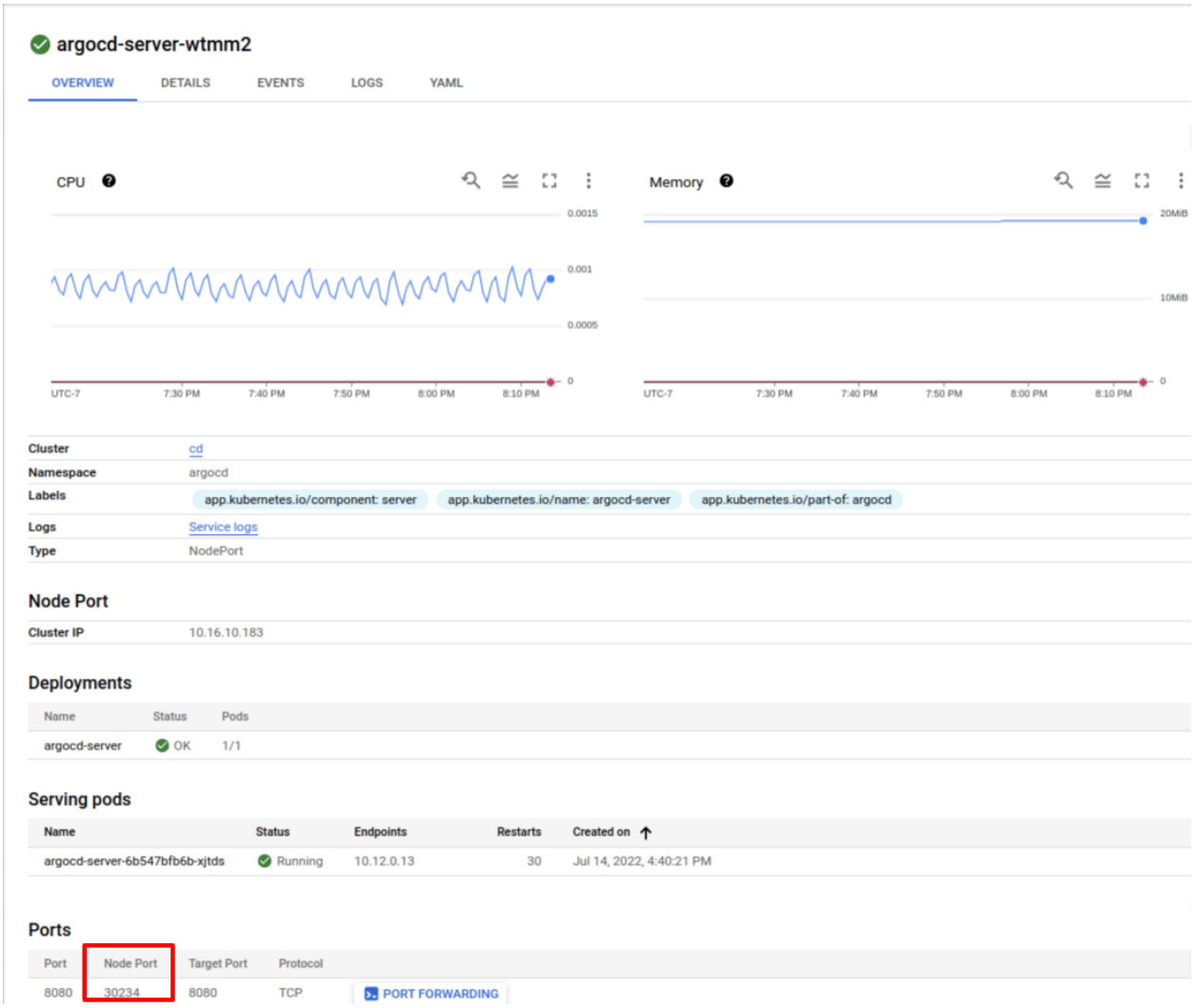


ArgoCD is served on port 8080, so enter 8080 into **Port 1** and select **Node port** from the **Service type** dropdown menu.



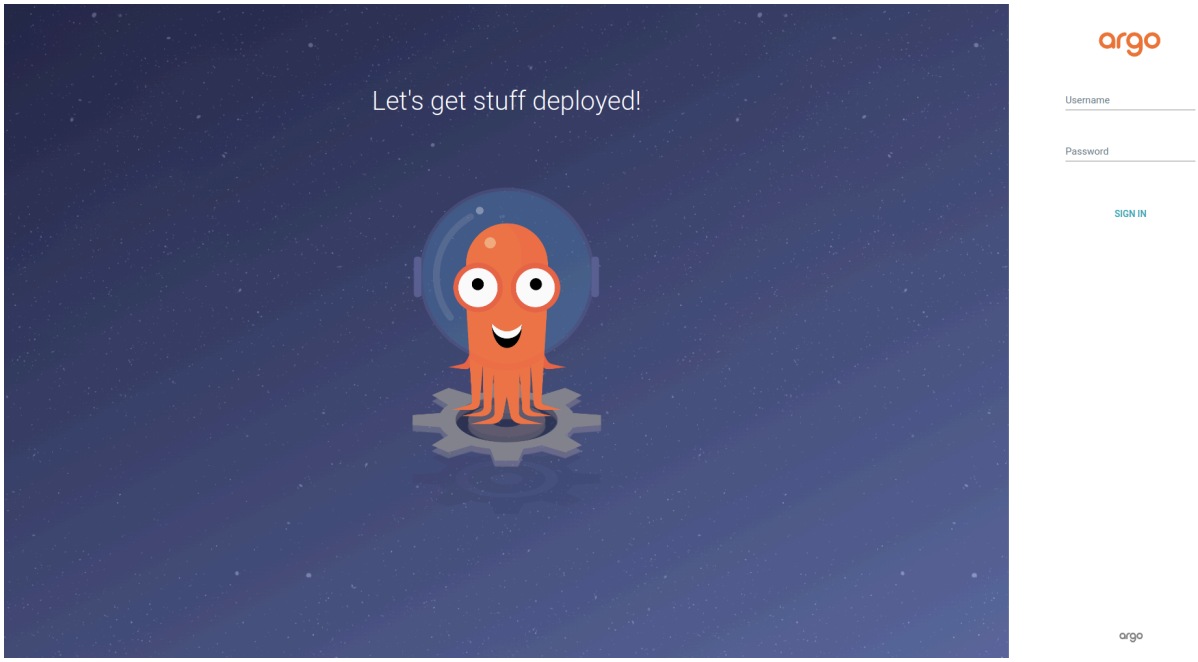
Finally, click **EXPOSE**.
Exposing a workload on a Node Port automatically generates a service. The service will be named **`argo-cd-server-xxxx`**. **`xxxx`** is a randomly generated ID that will be different for everyone.

To get Argo CD's Node Port, navigate to **Kubernetes Engine > Gateways, Services and Ingress > argo-cd-server-xxxxx**.

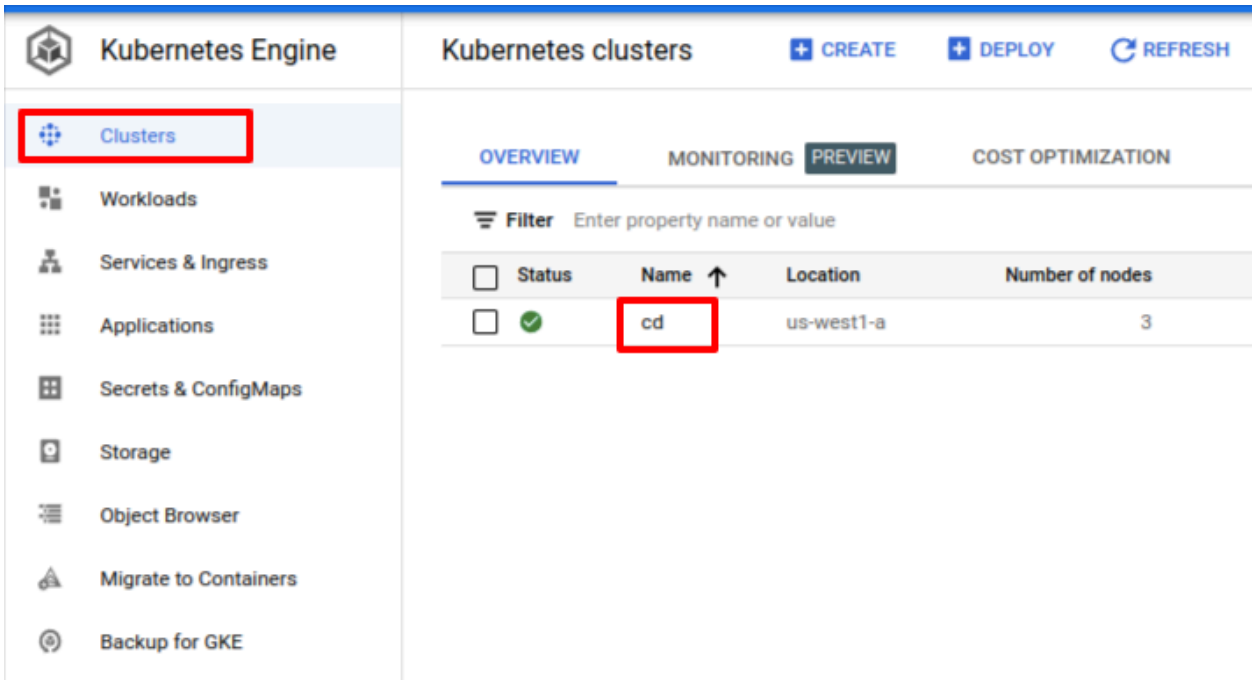


Visit one of the nodes' IP address with the Node Port like so: `NODEIPADDRESS:NODEPORT`

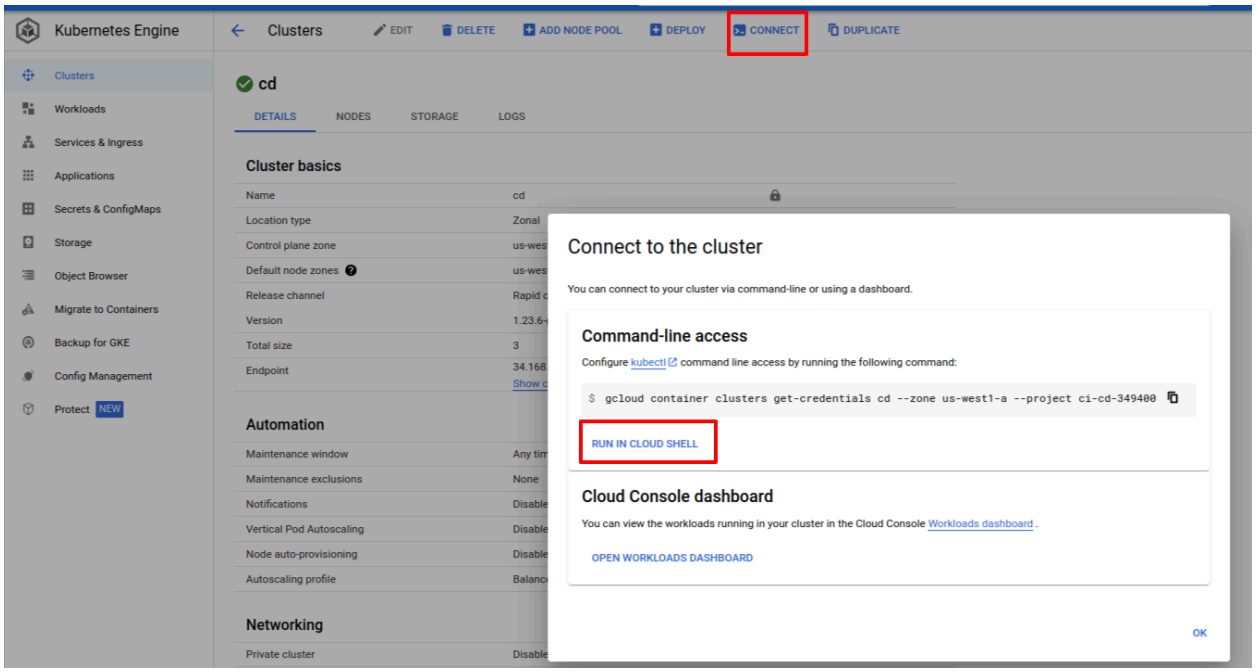
You will get a warning. Click **Advanced** and click to proceed to the URL. You should now see ArgoCD's home page.



The username is **admin**. We need to get the password that was automatically generated during install. To get the password, connect to your cluster:



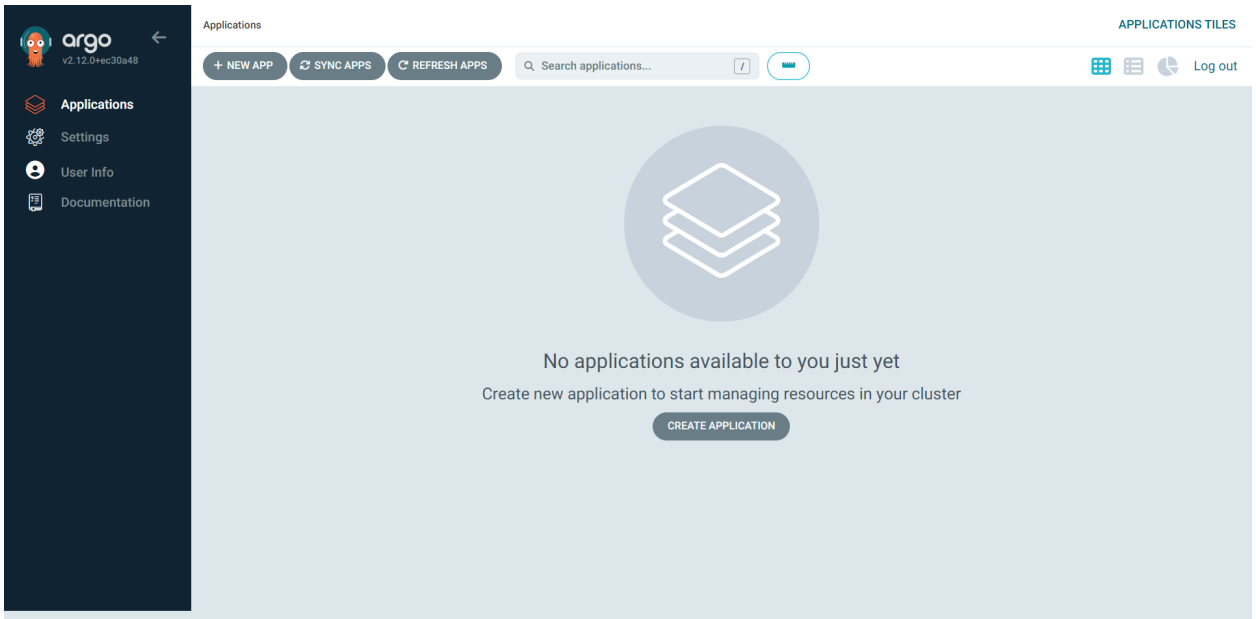
Run the cloud shell:



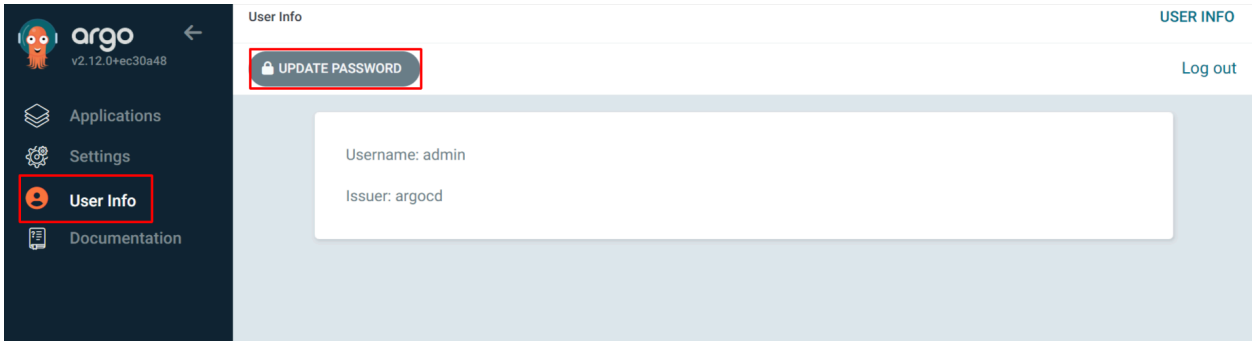
Run the following command inside the terminal:

```
$ kubectl -n argocd get secret argocd-initial-admin-secret -o
jsonpath="{.data.password}" | base64 -d; echo
```

The output is the password for ArgoCD. Enter **admin** as your username and the output of the above command as the password.



In order to change the password, click the user icon and then password:



The password must be at least eight characters long.

Setting Up Our Git Repository

Create a new repository on GitHub named **`vote-deploy`**. This could be named anything you want.

Add a file in the root directory of the repository called **`vote-ui-deployment.yaml`** and paste the following into it:

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: vote-ui
spec:
  replicas: 1
  revisionHistoryLimit: 3
  selector:
    matchLabels:
      app: vote-ui
  template:
    metadata:
      labels:
        app: vote-ui
    spec:
      containers:
    - image: docker.io/xxxx/vote
        name: vote-ui
        ports:
        - containerPort: 80
```

The code can be found here:
https://raw.githubusercontent.com/lftraining/LFS261-example-voting-app/refs/heads/master/gists/vote-ui-deployment.yaml

Be sure to replace **xxxx** with your own Docker Hub ID.

Add another file in the root directory of the repository called **vote-ui-svc.yaml** and paste the following into it:

```
apiVersion: v1
kind: Service
metadata:
  name: vote-ui
spec:
  type: NodePort
  ports:
  - port: 80
    targetPort: 80
    protocol: TCP
    name: http
  selector:
    app: vote-ui
```

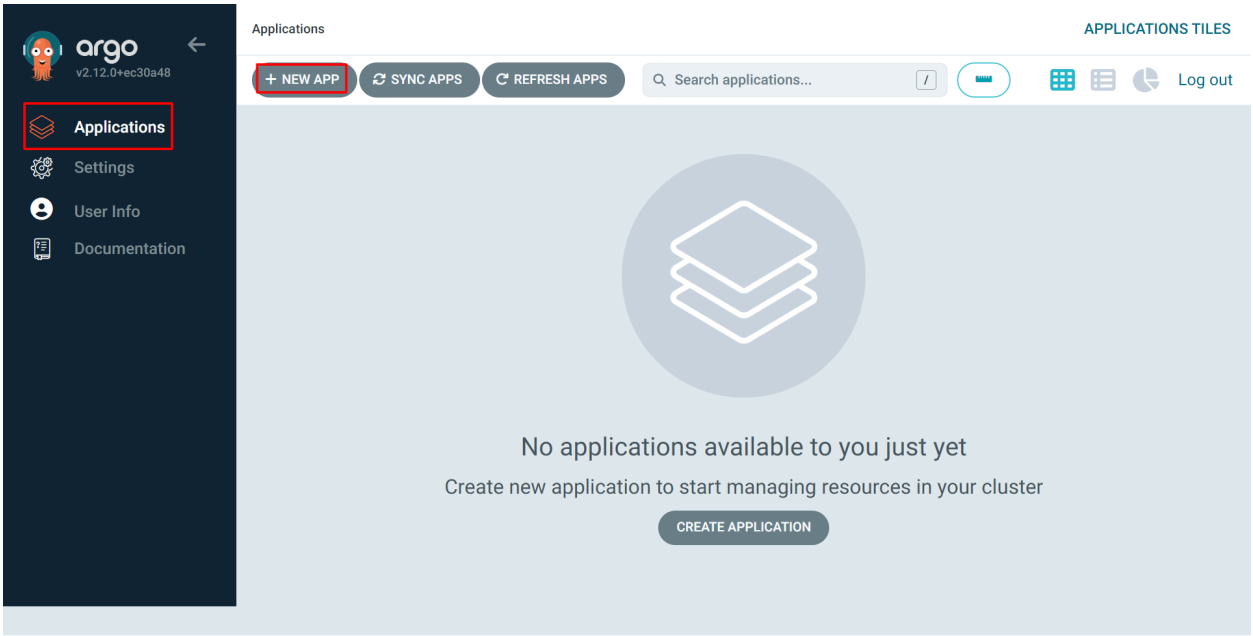
The code can be found here:
https://raw.githubusercontent.com/lftraining/LFS261-example-voting-app/refs/heads/master/gists/vote-ui-svc.yaml

If you did this in a local repository, make sure it is pushed to GitHub so that Argo CD can access the repository.

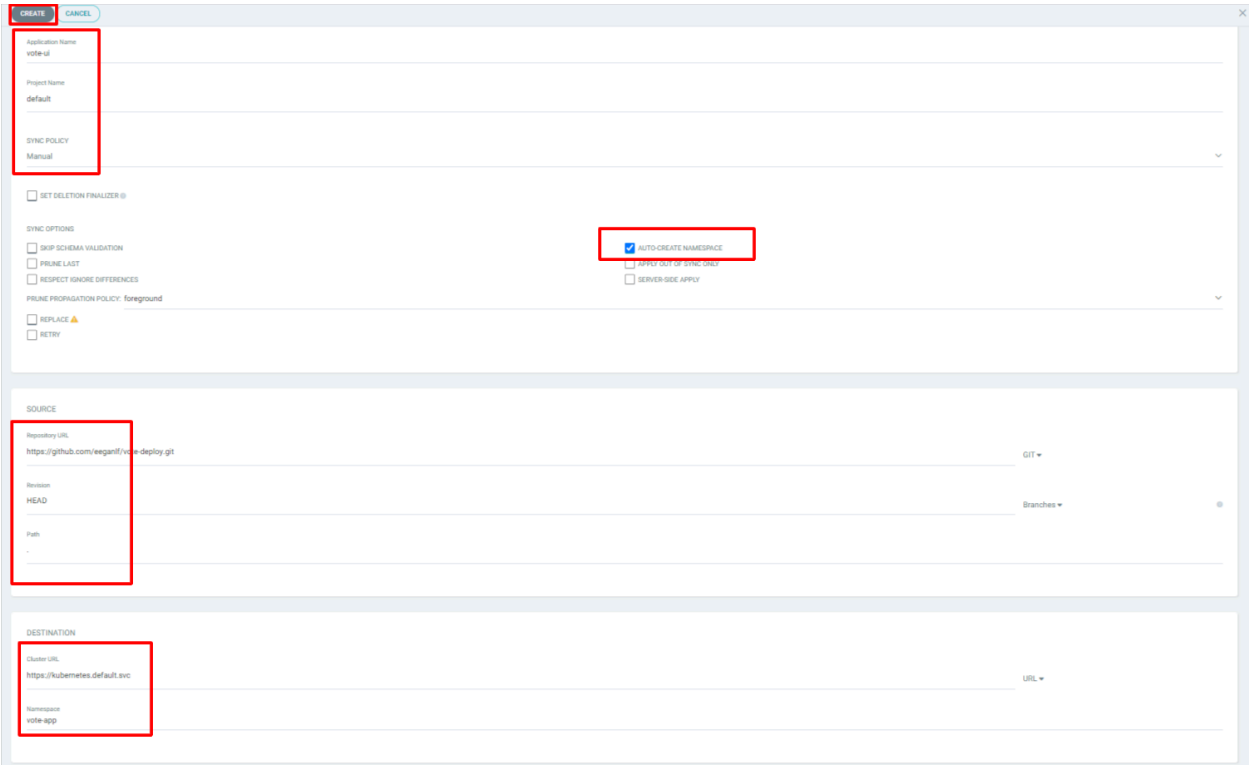
Deploying Our Vote Front End

Now we will set up our vote application in Argo CD.

First, click **+ NEW APP**:

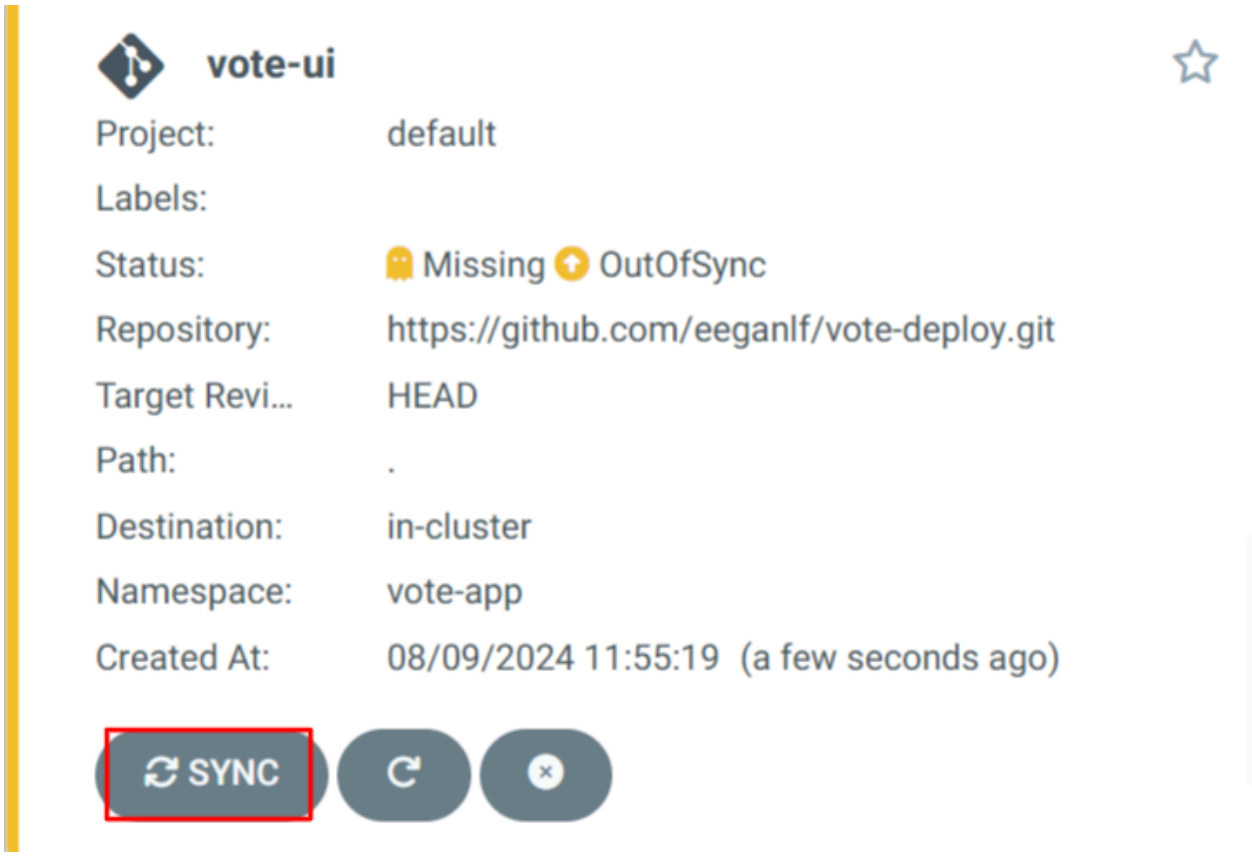


Enter **`vote-ui`** as the **Application Name**. Make sure **Project Name** is set to **default**. Check **AUTO-CREATE NAMESPACE**. Paste the URL to the **`vote-deploy`** GitHub repository. Make sure **HEAD** is chosen as the **Revision**. **Path** needs to be a period like so: '.'. This tells Argo CD that our yaml files are inside the root directory of our repository. Choose **`https://kubernetes.default.svc`** from the **Cluster URL** drop down and enter **`vote-app`** as the **Namespace**. Match the following:

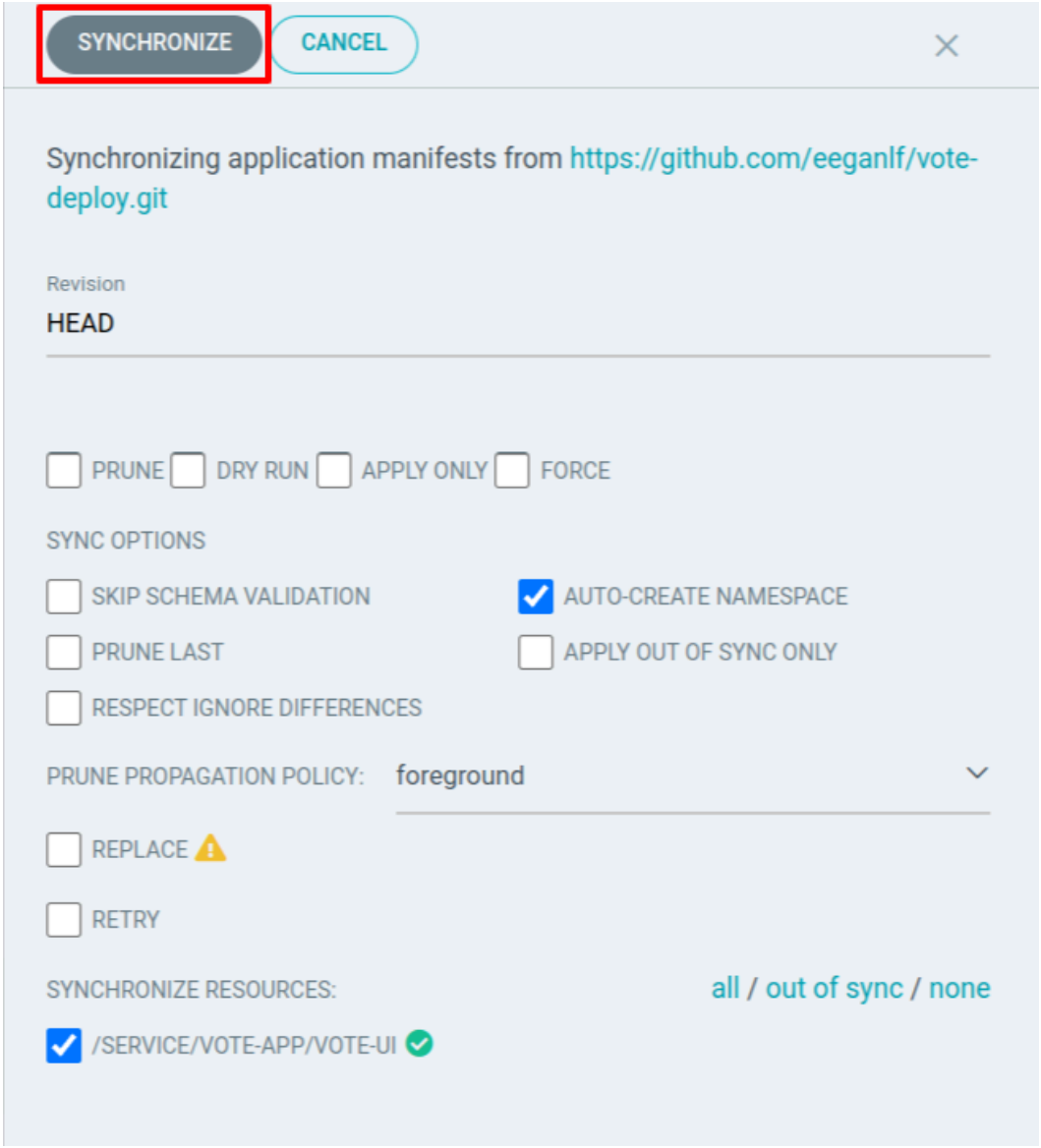


Finally, click **CREATE**.

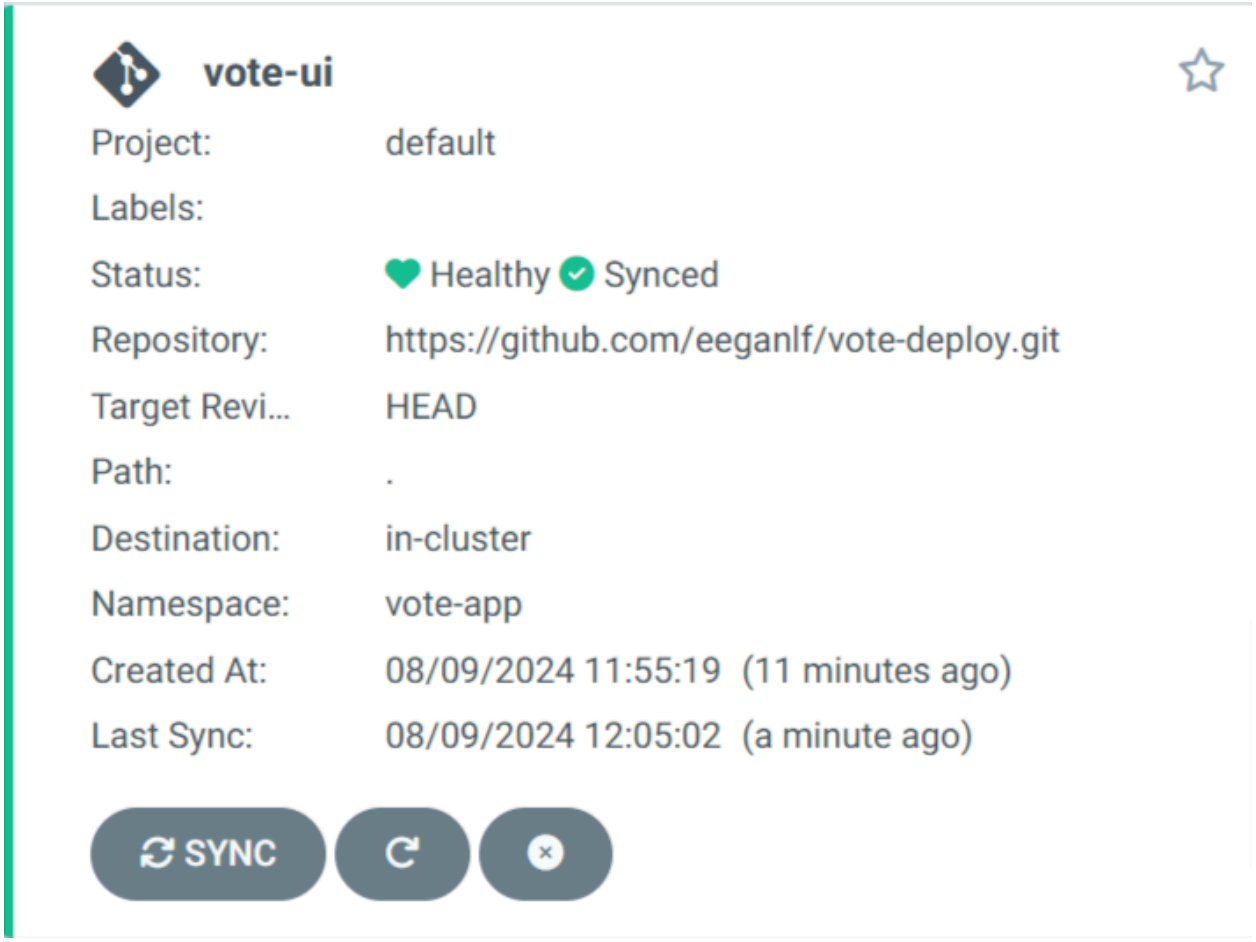
The application should show up automatically in the Argo UI:



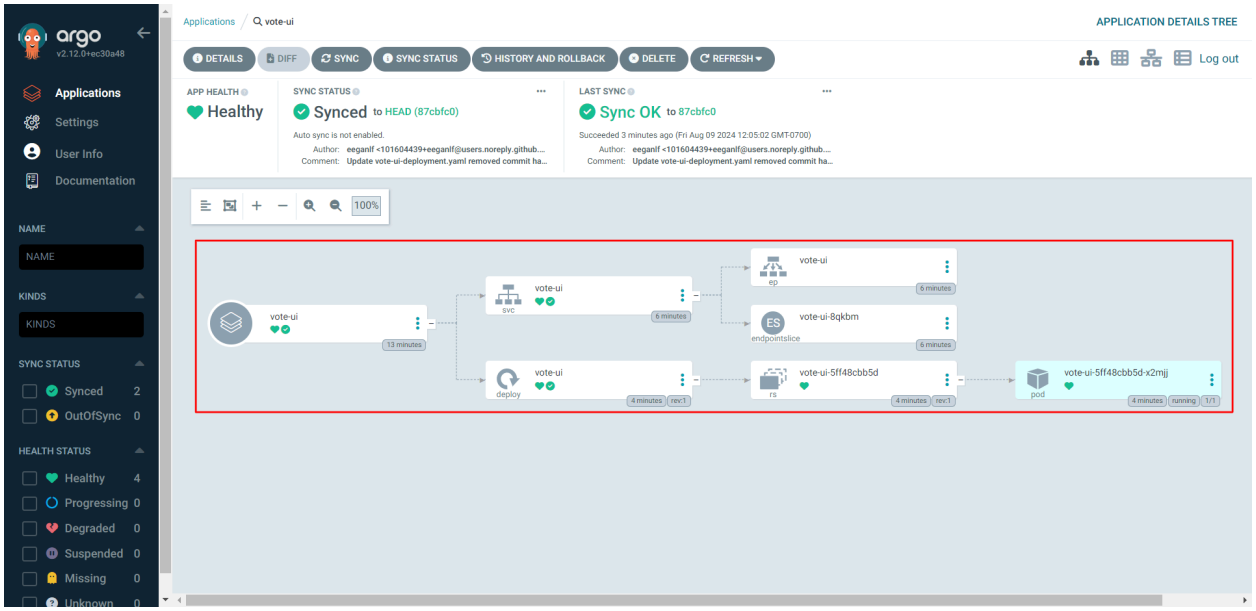
Click **SYNCHRONIZE.** A fly-out will appear:



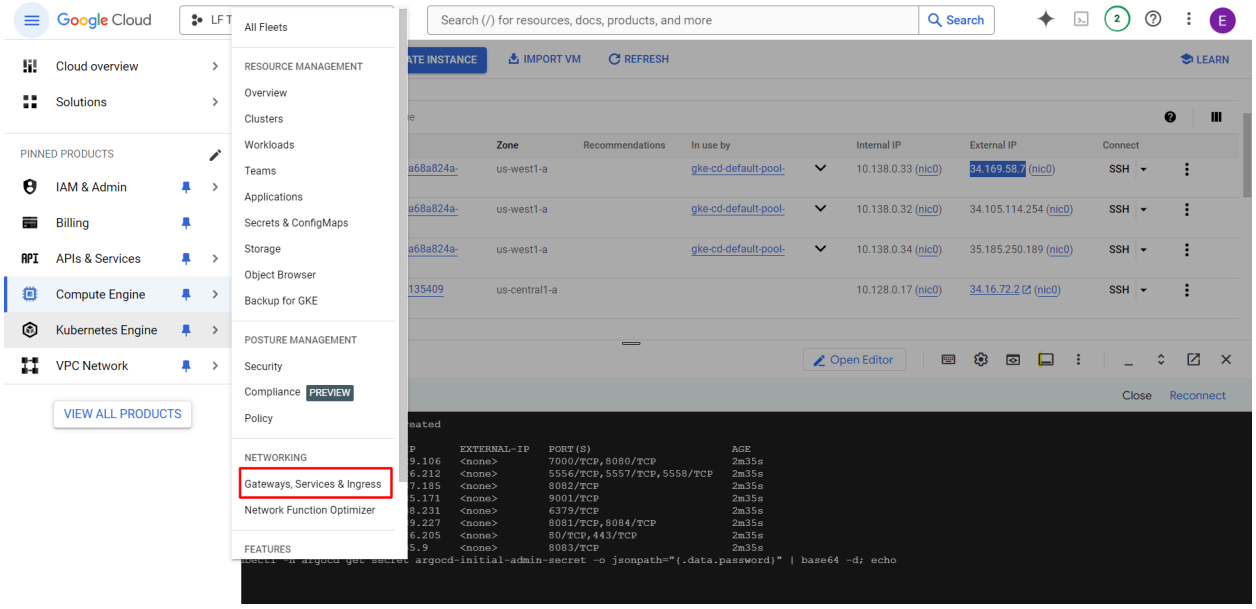
Click on the card:

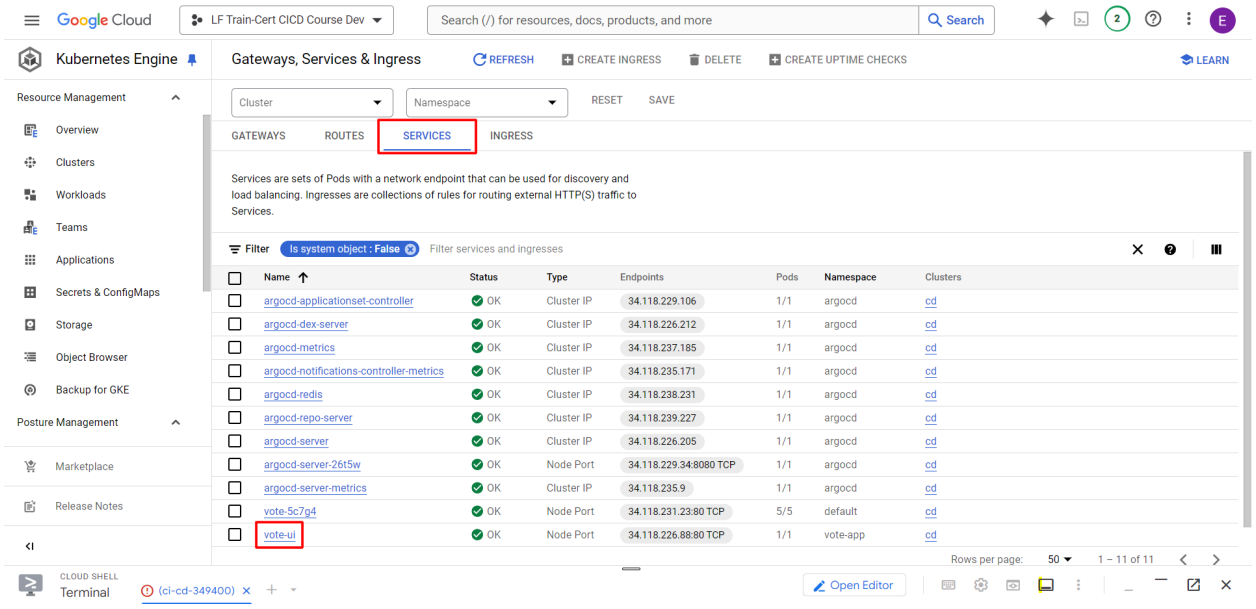


We can see that Argo CD has deployed our **`vote-ui`** application:

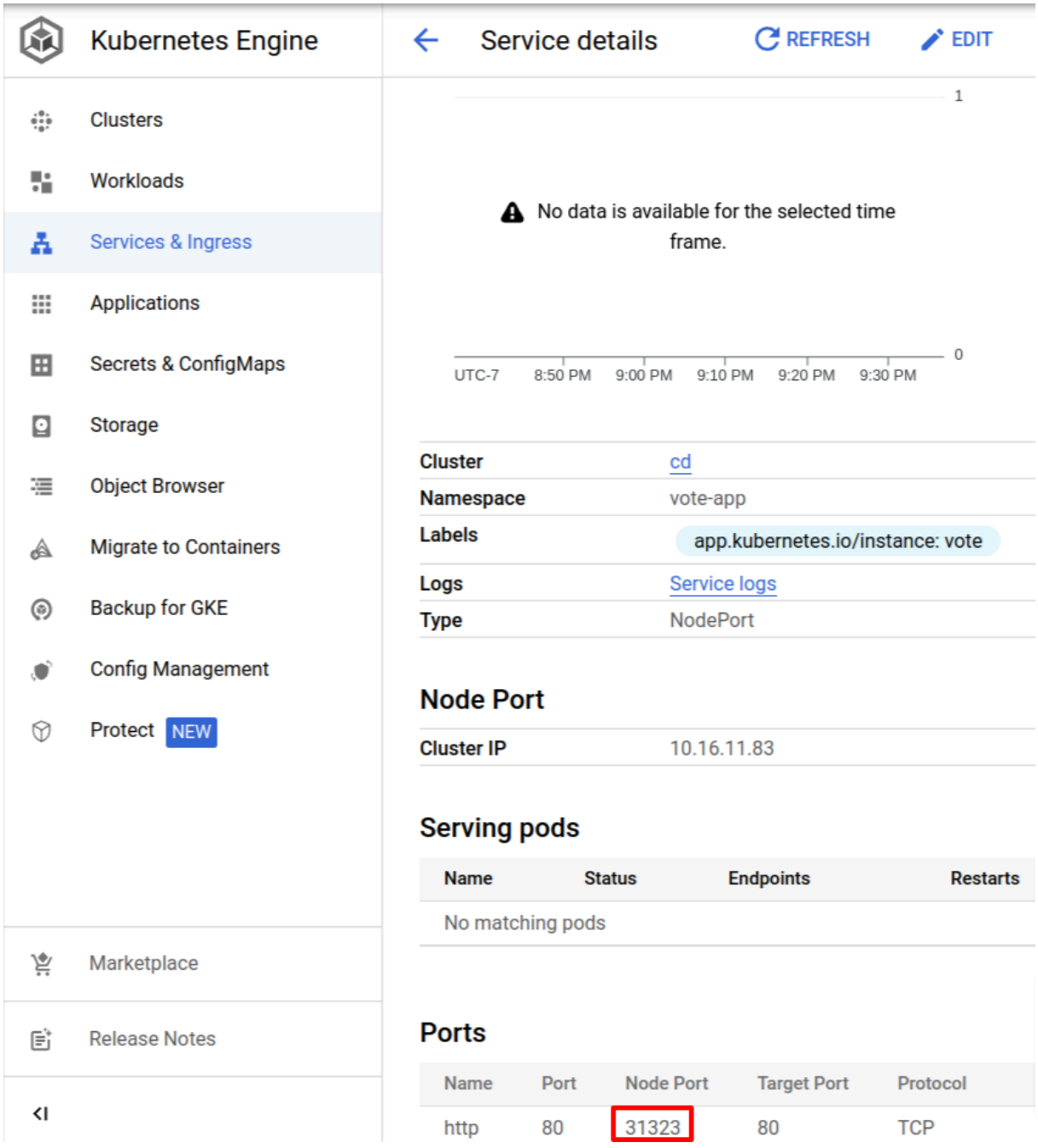


To visit your **`vote-ui`**, get its Node Port by navigating to **Google Cloud > Kubernetes Engine > Gateways, Services & Ingress > vote-ui**:

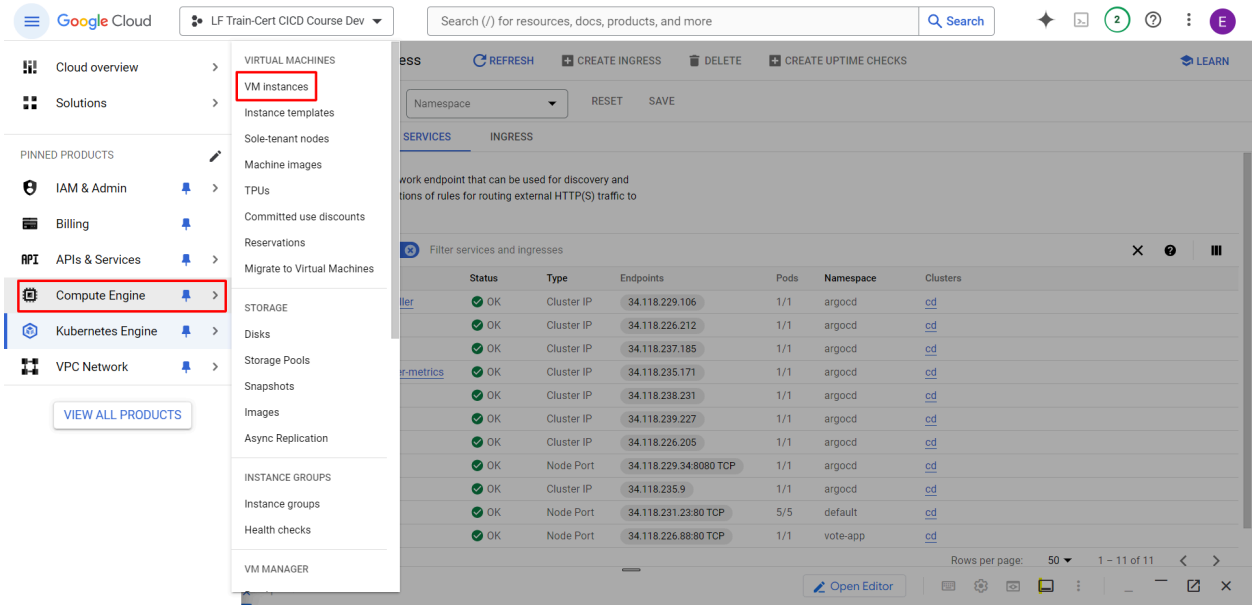


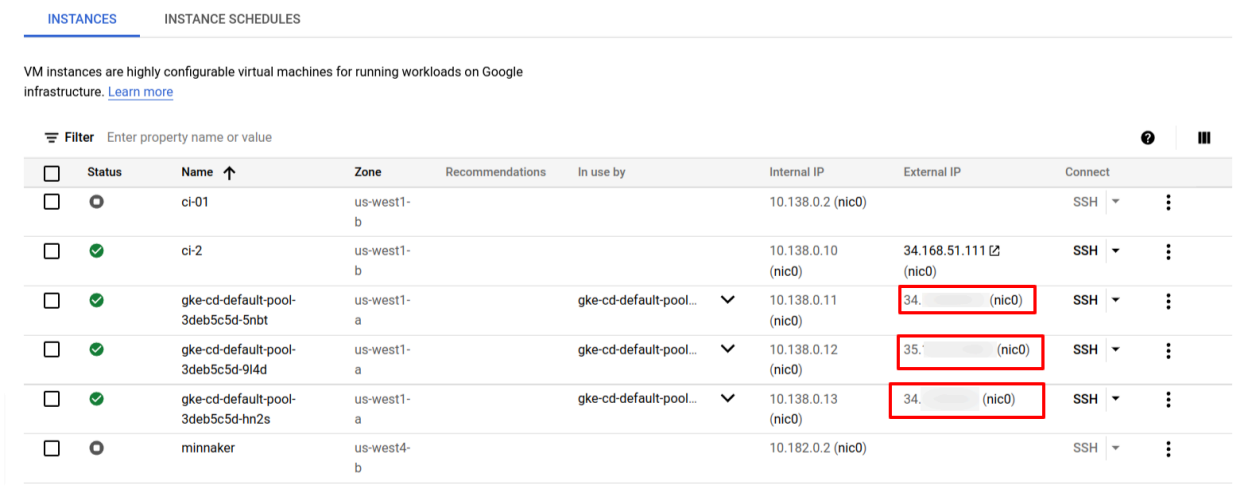


Scroll to the bottom and take note of the NodePort. Yours will likely be different than anyone else's:

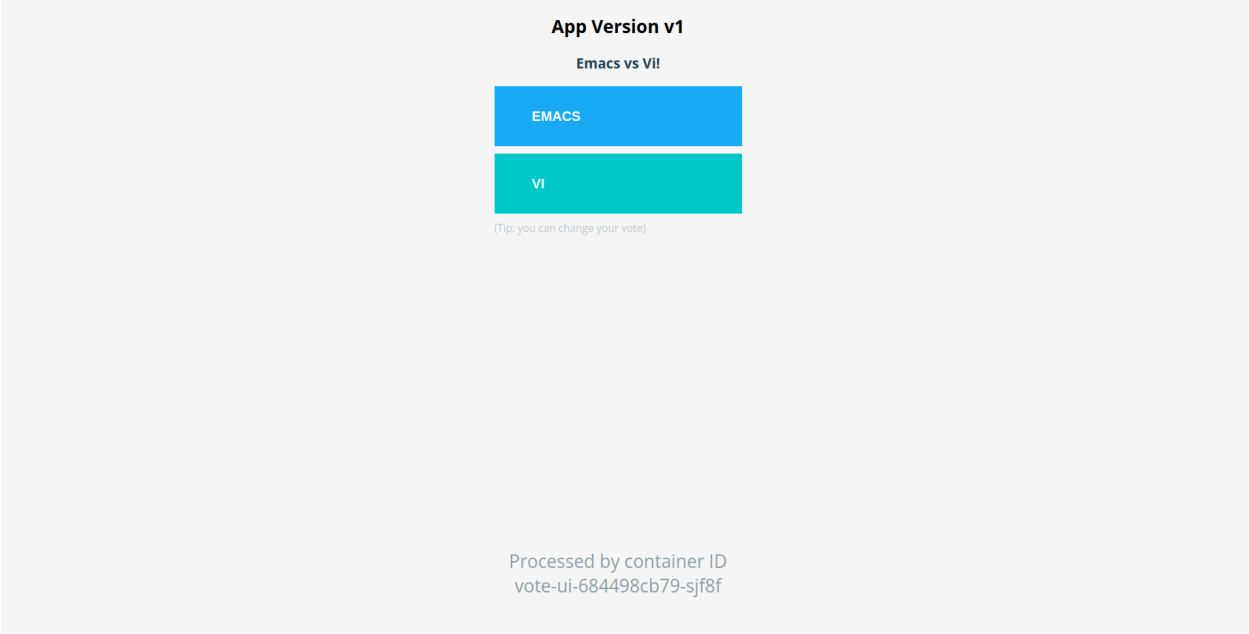


Obtain any one of your node's IP addresses by going to **Google Cloud > Compute Engine > VM instances**:





Visit one of your node IPs with the NodePort of your `vote-ui` service and you should see the vote application UI:

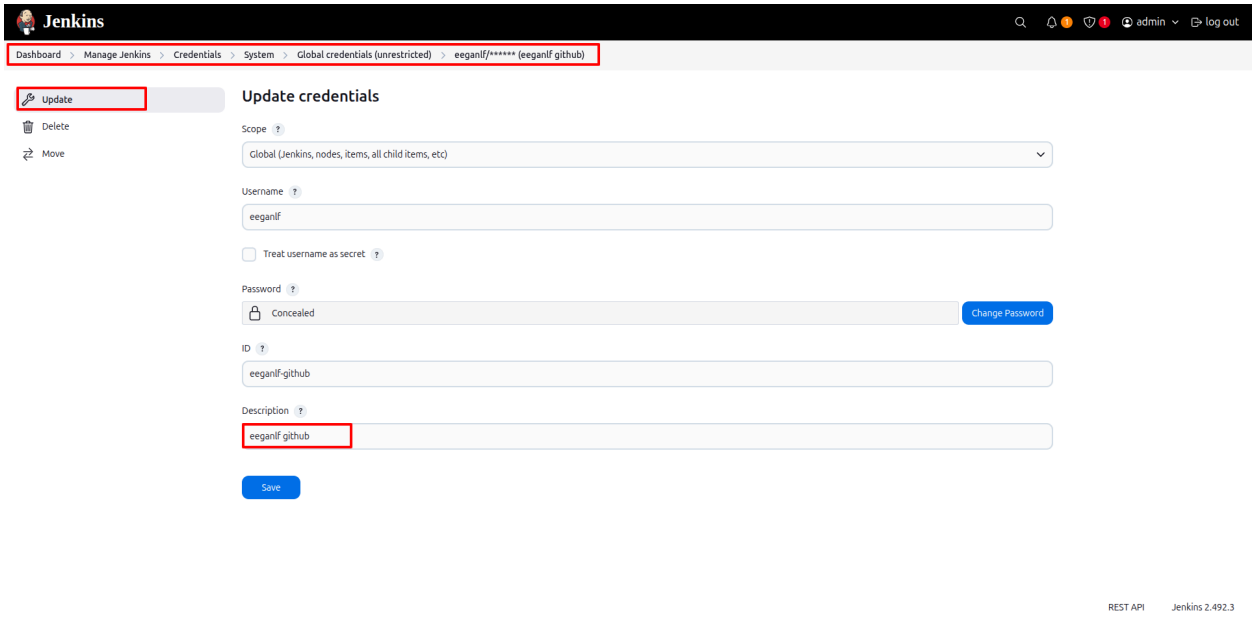


Set Argo CD to Continuous Deployment

In the previous section, you had to manually instruct Argo CD to synchronize the cluster with changes made in the `vote-deploy` repository. To implement Continuous Deployment, you must configure the Argo CD application to auto-sync. To do this, the next section will guide you through the steps to set up a Jenkins deployment pipeline and then configure Argo CD to automatically deploy our application.

Creating the **deployment** Pipeline

First, you will need the description of your GitHub credentials. Refer to the following and take note of the description in the **Description** box:



Add a **Jenkinsfile** to your **vote-deploy** Git repository that you created earlier.

Add the following code and be sure to replace the red text with your own information and please NOTE: JenkinsGithubCredsDescription needs to be replaced with the DESCRIPTION found in the Description text box of your GitHub credential that you just took note of. It is NOT the text found in the ID text box:

```
node {
    def app

    stage('Clone repository') {


        checkout scm
    }

    stage('Update GIT') {
            script {
                catchError(buildResult: 'SUCCESS', stageResult:
'FAILURE') {
                    withCredentials([usernamePassword(credentialsId:
'JenkinsGithubCredsDescription', passwordVariable: 'GIT_PASSWORD',
usernameVariable: 'GIT_USERNAME')]) {
                        sh "git config user.email
yourGitHubEmail@email.com"
                        sh "git config user.name yourGitHubUsername"
                        sh "cat vote-ui-deployment.yaml"
```

```
                        sh "sed -i
's+dockerHubUserName/vote.*+dockerHubUsername/vote:${DOCKERTAG}+g'
vote-ui-deployment.yaml"
                        sh "cat vote-ui-deployment.yaml"
                        sh "git add ."
                        sh "git commit -m 'Done by Jenkins Job
deployment: ${env.BUILD_NUMBER}'"
                        sh "git push
https://${GIT_USERNAME}:${GIT_PASSWORD}@github.com/${GIT_USERNAME}/vot
e-deploy.git HEAD:master"
      }
    }
  }
}
}
```

The code can be found here: https://raw.githubusercontent.com/lftraining/LFS261-example-voting-app/refs/heads/master/gists/LFS261ArgoDeployJenkinsfile

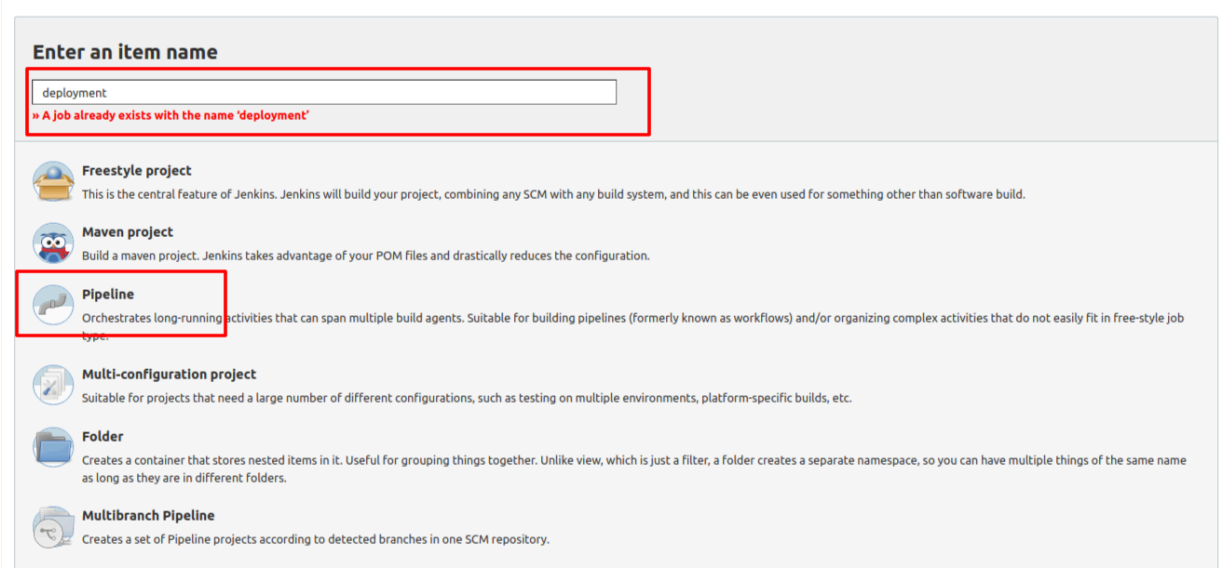
If you did this in a local repository, make sure it is pushed to GitHub so that Jenkins can access the file.

Your **vote-deploy** repository should now contain three files:

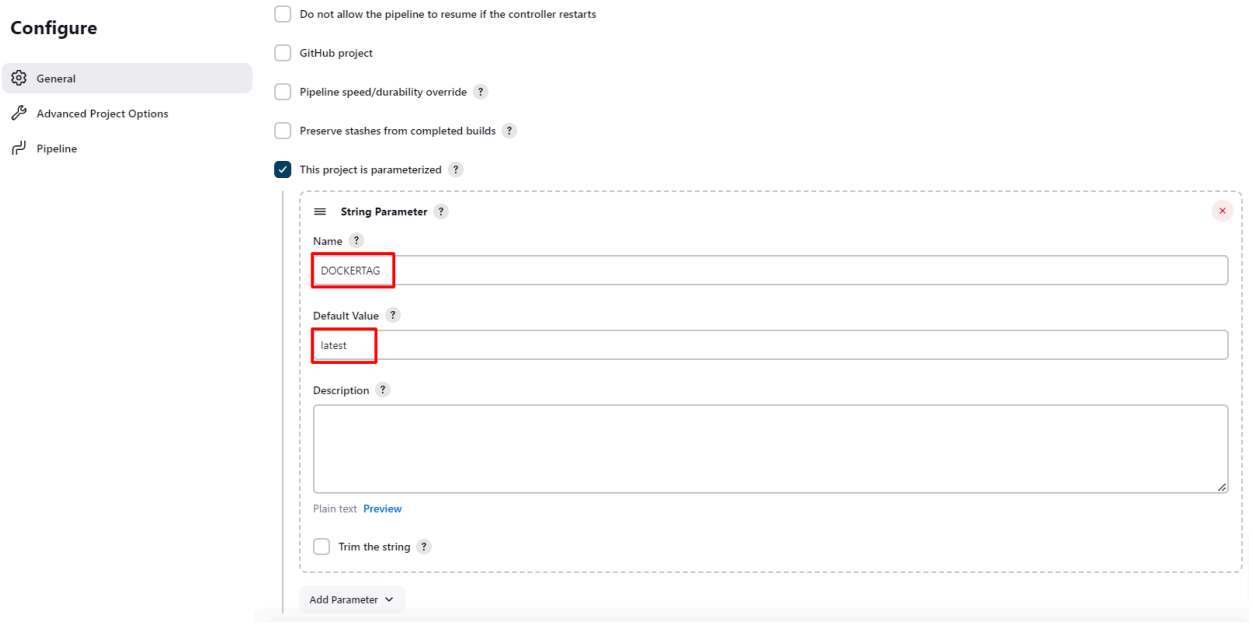
```
Jenkinsfile
vote-ui-deployment.yaml
vote-ui-svc.yaml
```

In Jenkins, you will now create a **deployment** pipeline that will update the **vote-deploy** repository.

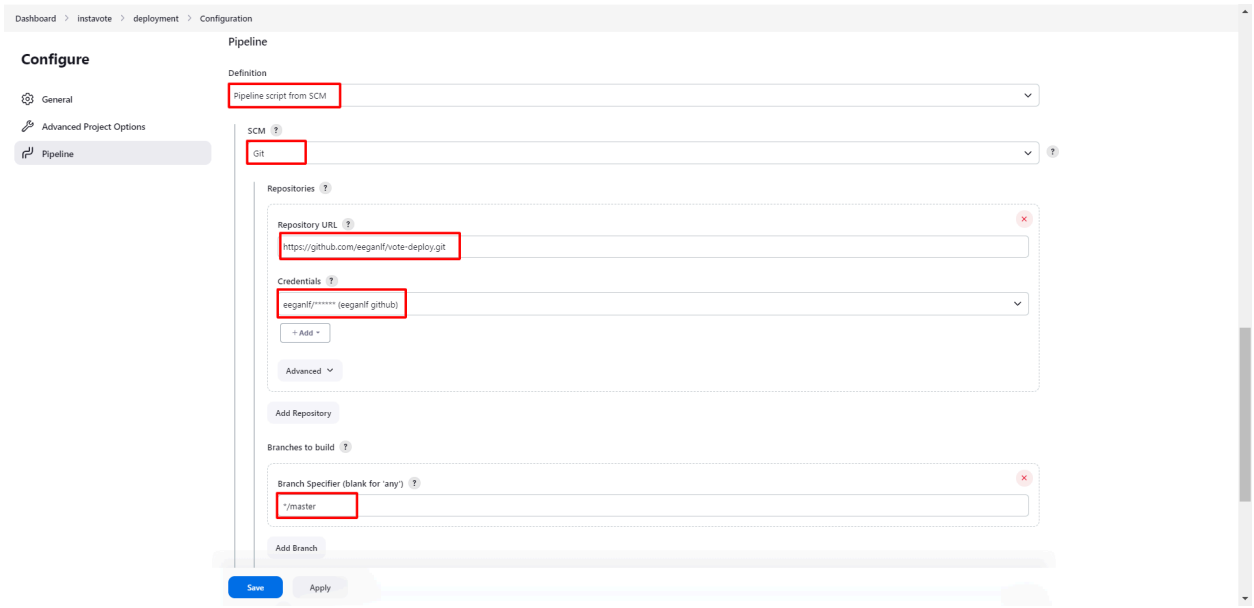
Create the **deployment** pipeline by clicking **New Item** on the Jenkins homepage.The job must be called **deployment**. Then choose **Pipeline**:



You must mark this pipeline as *parameterized* and tell the job which variable is being passed to it. Under the **General** tab, select **This project is parameterized**. Click the **Add Parameter** dropdown menu and select **String Parameter**. Give the parameter the name **DOCKERTAG** and the default as `latest` as follows:



Under the **Pipeline** section, fill out as follows, using your forked repository of the deployment repository:



Click **Save**.

Triggering Deployment Pipeline

To achieve continuous deployment we need Jenkins to automatically update our deployment repository. Argo CD is watching this repository for changes and will automatically deploy our application to Kubernetes when it notices a change.

To do this, we need to add the following stage as the *final stage* in the **`stages`** section to our **`example-voting-app/Jenkinsfile`**:

```
stage('Trigger deployment') {
   agent any
   environment{
    def GIT_COMMIT = "${env.GIT_COMMIT}"
   }
   steps{
    echo "${GIT_COMMIT}"
    echo "triggering deployment"
    // passing variables to job deployment run by vote-deploy
repository Jenkinsfile
    build job: 'deployment', parameters: [string(name: 'DOCKERTAG',
value: GIT_COMMIT)]
   }
}
```

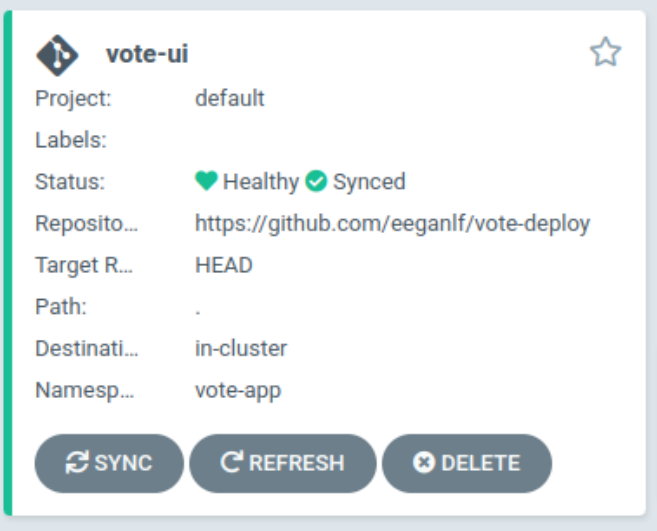
Find the code at the following link:
https://raw.githubusercontent.com/lftraining/LFS261-example-voting-app/refs/heads/master/gists/Continuous-Deploy-Stage-Jenkinsfile

Recall that our CI pipeline is already configured to look for this Jenkinsfile.

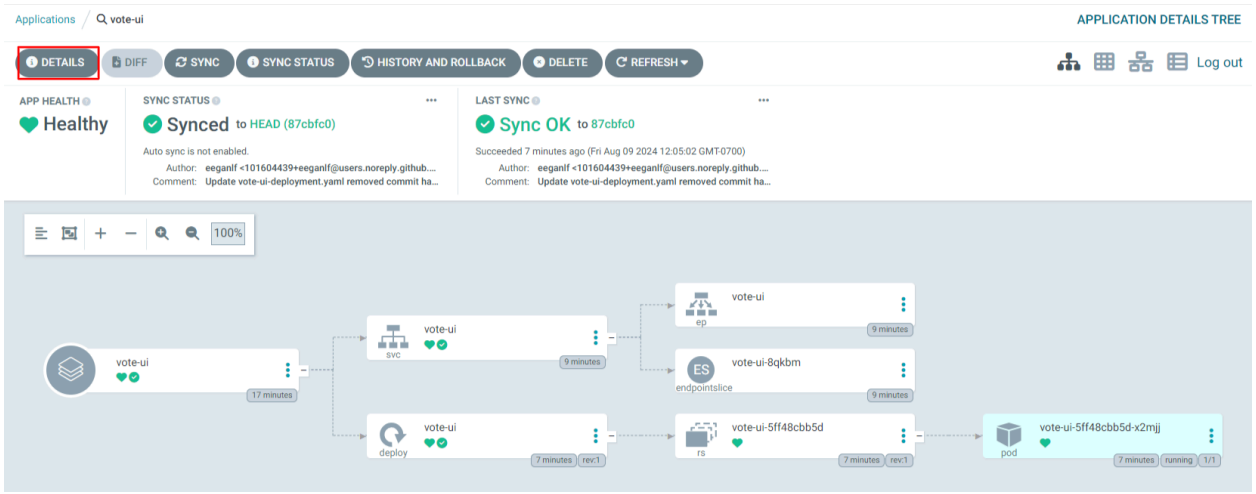
Commit all changes.

Setting Argo CD to Continuously Deploy

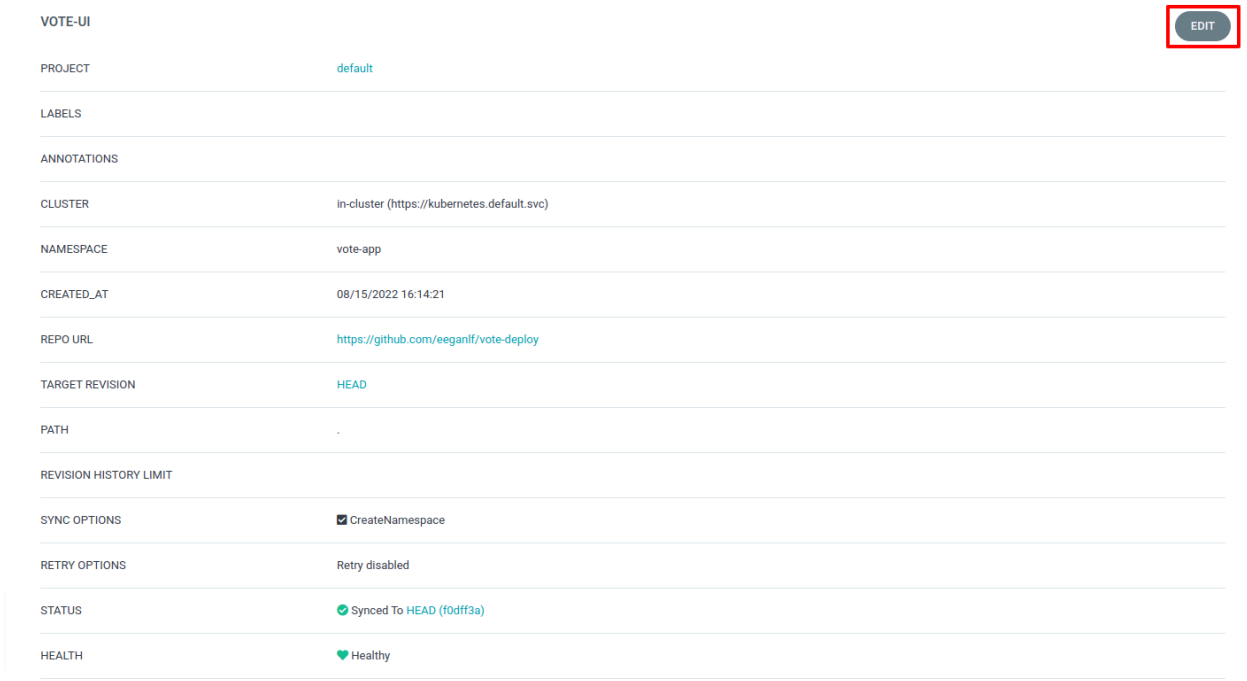
In Argo CD, click on the vote-ui card:



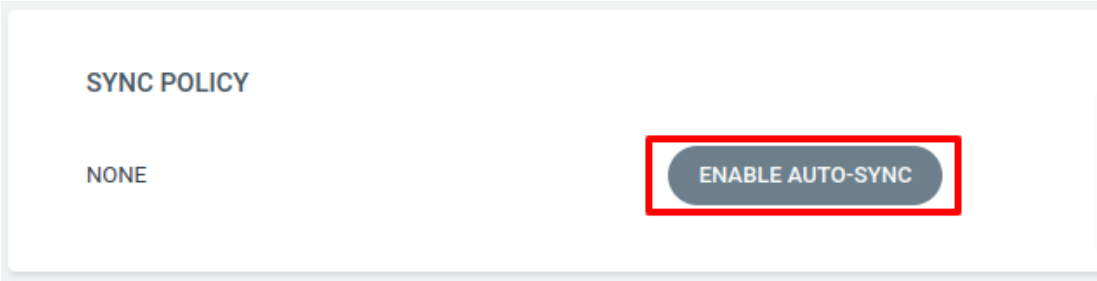
Then click on **DETAILS**:



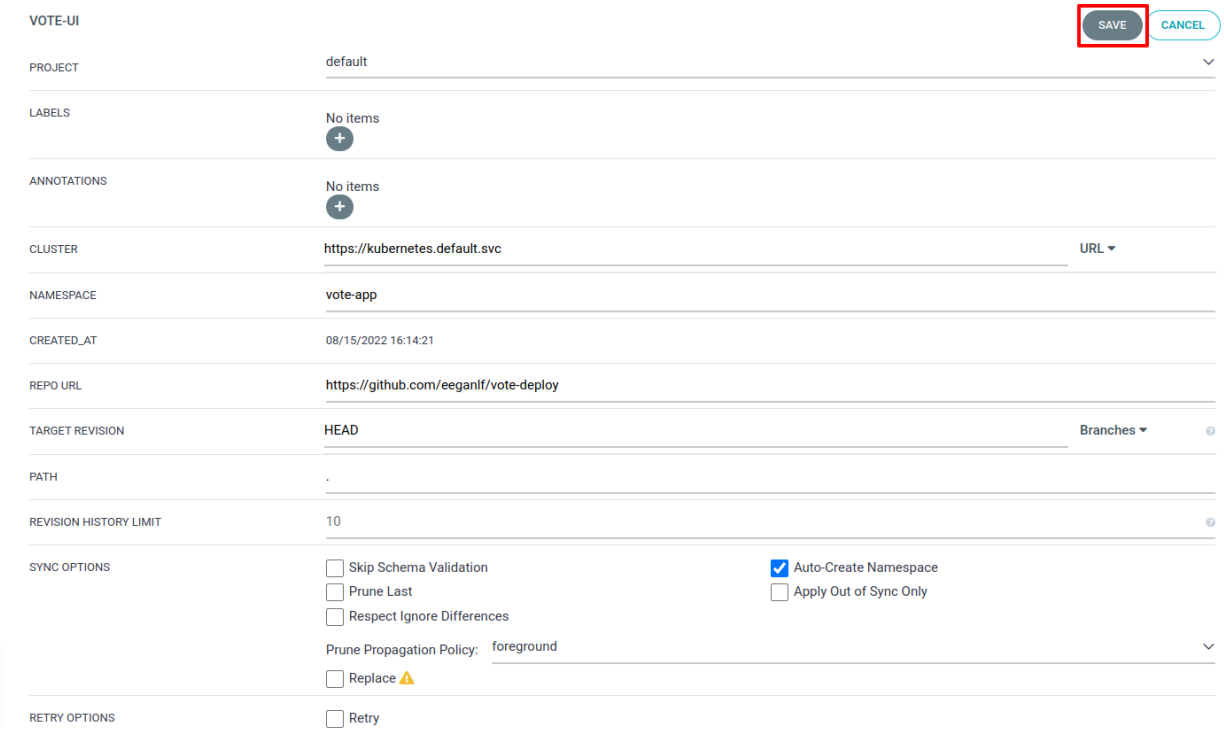
Then click **EDIT:**



Scroll to **SYNC POLICY** and select **ENABLE AUTO-SYNC:**



Scroll back to the top and click **SAVE**:

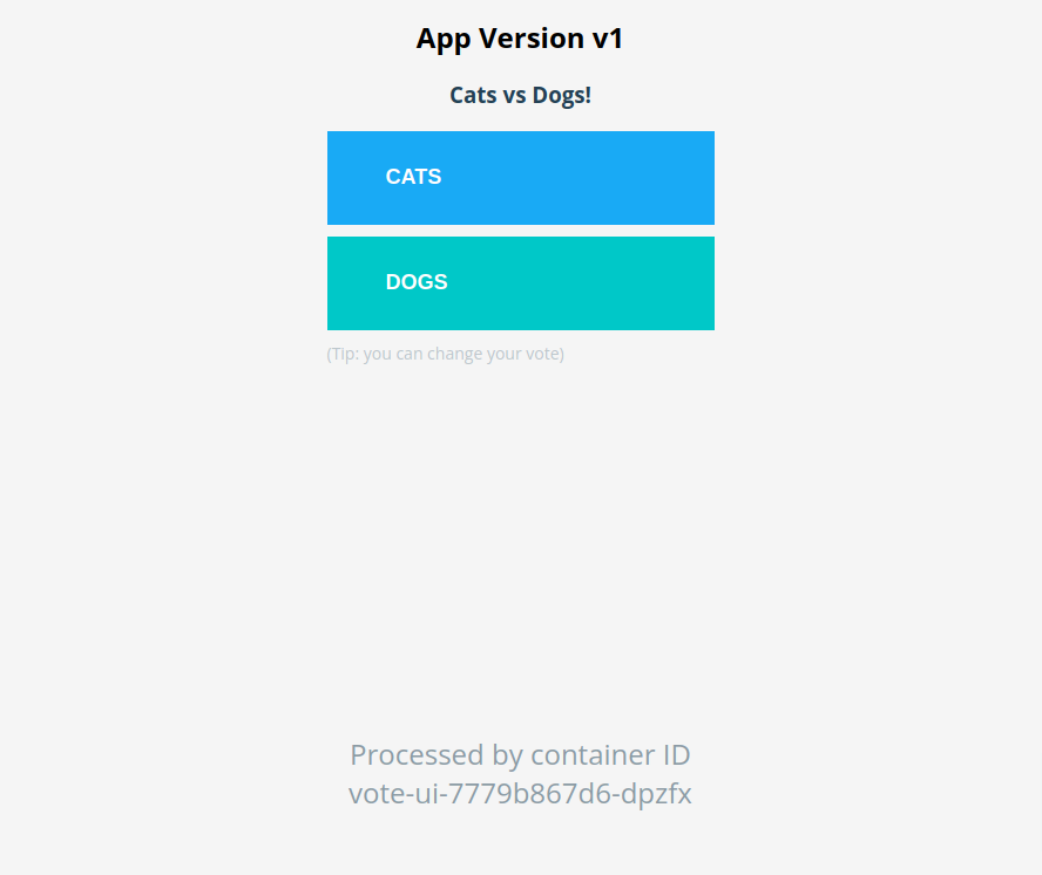


Auto Deploy Changes

Change line 8 and 9 of `example-voting-app/vote/app.py` from **emacs** and **Vim** to **Cats** and **Dogs** as follows:

```
48 lines (38 sloc)  1.14 KB
1  from flask import Flask, render_template, request, make_response, g
2  from redis import Redis
3  import os
4  import socket
5  import random
6  import json
7
8  option_a = os.getenv('OPTION_A', "Cats")
9  option_b = os.getenv('OPTION_B', "Dogs")
10 hostname = socket.gethostname()
11 version = 'v1'
12
13 app = Flask(__name__)
14
```

Commit your changes. After the **`deployment`** pipeline is complete, wait a few minutes for Argo CD to see the changes in the **`vote-deploy`** repository. Visit the public IP of one of your instances with the NODE PORT of the **`vote-ui`** as before and you should see the changes:



Congratulations! You have achieved CI/CD and Continuous Deployment with Jenkins, Kubernetes, and Argo CD.

Lab Summary

In this lab, we configured Argo CD to deploy the frontend of our example voting application and set up Continuous Deployment.