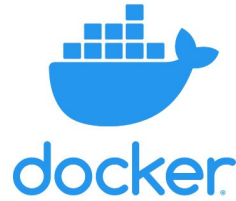


# Containers



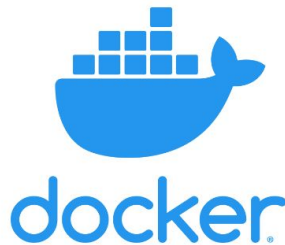
# Introduction

## What is a Container?

Containers are **packages of software that contain all of the necessary elements to run in any environment.**

- software or code functions in exactly the same way regardless of where it's executed (mac/windows, cluster/local)
- Containers are in many ways similar to virtual machines but more lightweight.
- Containers can be used to allow others to reproduce a complete analysis
- Containers can also be used to define software environments and settings for benchmarking studies

Making self-contained, distributable projects with



# The battle



runs as a daemon process with superuser privileges

images stored centrally

isolates the host and container file system by default

well supported on Mac/Linux/Windows

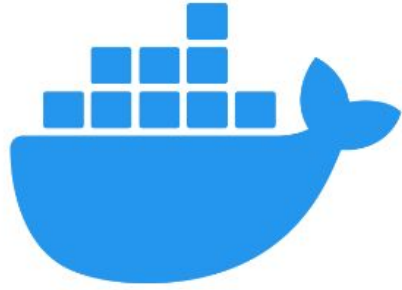


runs as regular user

image files that you can move around. No layers!

containers have access to host file system

limited support on Mac/Windows



docker<sup>®</sup>



Standardized packaging for software and dependencies

Docker lets you create and run applications securely isolated in a container, packaged with all its dependencies and libraries.

Docker nomenclature:

A **Docker file** is a recipe used to build a Docker image

A **Docker image** is a standalone executable package of software

A **Docker container** is a standard unit of software run on the Docker Engine.

**Docker Hub** is an online service for sharing docker images

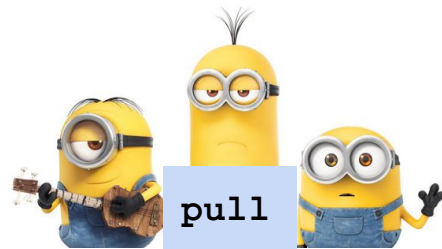
# The basics

## Downloading containers

```
docker pull ubuntu:latest  
docker image ls
```

## Running containers

```
docker run ubuntu uname -a
```



## Running interactively

```
docker run -ti ubuntu
```

```
# -t terminal connection btw shell
```

```
# -i interactif
```

```
# -v bind mount volume
```

```
# -w workdir inside the container
```

```
...
```

## Containers inside scripts



```
shell:
    """
    bowtie2-build tempfile intermediate/{wildcards.genome_id} > {log}
    """
```

```
$curl -o NCTC8325.fa.gz URL_to_file.fa.gz
```

```
$gunzip -c NCTC8325.fa.gz > tempfile
```

```
docker run -v /path/to/dir/analysis:/home
```

```
quay.io/biocontainers/bowtie2:2.5.0--py310h8d7afc0_0 bowtie2-build  
/home/tempfile /home/NCTC832
```



# Building a docker image

## Format

Here is the format of the `Dockerfile` :

```
# Comment  
INSTRUCTION arguments
```

FROM  
LABEL  
MAINTAINER  
SHELL  
WORKDIR  
RUN  
ENV  
EXPOSE  
CMD  
COPY  
...

**FROM** ubuntu:16.04



**FROM** my\_docker\_image:latest

+ layers !!!



# Understanding from Dockerfiles

**FROM** ubuntu:16.04

**LABEL** description = "Minimal image for the NBIS reproducible research course."

**MAINTAINER** "John Sundh" john.sundh@scilifelab.se

# Use bash as shell

**SHELL** ["/bin/bash", "-c"]

# Set workdir

**WORKDIR** /course

# Install necessary tools

**RUN** apt-get update && \  
apt-get install -y --no-install-recommends bzip2 \  
ca-certificates \  
curl \  
[...]  
unzip \  
wget \  
&& apt-get clean

FROM ubuntu:16.04

LABEL description = "Minimal image for the NBIS reproducible research course."

MAINTAINER "John Sundh" john.sundh@scilifelab.se

# Use bash as shell

SHELL ["/bin/bash", "-c"]

# Set workdir

WORKDIR /course

# Install necessary tools

```
RUN apt-get update && \
    apt-get install -y --no-install-recommends bzip2 \
        ca-certificates \
        curl \
        [...]
    unzip \
    wget \
    && apt-get clean
```



# Install necessary tools

RUN apt-get update

```
RUN apt-get install -y
--no-install-recommends bzip2 \
    ca-certificates \
    curl \
    [...]
    unzip \
    wget
```

RUN apt-get clean

# Install Miniconda and add to PATH

```
RUN curl -L https://repo.continuum.io/miniconda/Miniconda3-4.7.12.1-Linux-x86_64.sh -O && \  
    bash Miniconda3-4.7.12.1-Linux-x86_64.sh -bf -p /usr/miniconda3/ && \  
    rm Miniconda3-4.7.12.1-Linux-x86_64.sh && \  
    /usr/miniconda3/bin/conda clean -tipsy && \  
    ln -s /usr/miniconda3/etc/profile.d/conda.sh /etc/profile.d/conda.sh && \  
    echo ". /usr/miniconda3/etc/profile.d/conda.sh" >> ~/.bashrc && \  
    echo "conda activate base" >> ~/.bashrc
```

# Add conda to PATH and set locale

```
ENV PATH="/usr/miniconda3/bin:${PATH}"
```

```
ENV LC_ALL en_US.UTF-8
```

```
ENV LC_LANG en_US.UTF-8
```

# Configure Conda channels and install Mamba

```
RUN conda config --add channels bioconda \  
    && conda config --add channels conda-forge \  
    && conda config --set channel_priority strict \  
    && conda install mamba \  
    && mamba clean --all
```

# Open port for running Jupyter Notebook

**EXPOSE** 8888

# Start Bash shell by default

**CMD** /bin/bash

And now it's your turn!



***TP : Building from Dockerfiles***

***TP : Creating your own Dockerfile***

# Building from Dockerfiles

```
docker build -f Dockerfile_slim -t my_docker_image .
```

```
-f dockerfile_recipe_name
```

```
-t tag
```

```
. /this/path
```

# Creating your own Dockerfile



```
FROM my_docker_image:latest
RUN mamba install -n base fastqc=0.11.9
RUN mamba install -n base sra-tools=2.11.0
COPY run_qc.sh .
CMD bash run_qc.sh
```



# Managing containers

```
docker run my_docker_conda
```

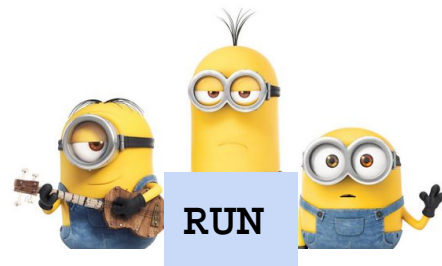
```
# -t terminal connection btw shell
```

```
# -i interactif
```

```
# -v bind mount volume
```

```
# -w workdir inside the container
```

```
...
```



```
docker run -d --rm --name my_container my_docker_conda  
# -rm remove docker image when run is finished  
# -d detached
```



```
docker containers ls --all
```

```
# -ls : list
```

```
# --all : show all the containers
```

check if container is running ...

**exec**  
**ps**

```
docker exec -it my_container_ID /bin/bash
```

@Jacques à dit : un container (avec ce nom) peut avoir runné plusieurs fois pour faire des choses différents... du coup il faut utiliser l'ID qui est unique pour savoir avec qui tu communique

```
docker ps
```

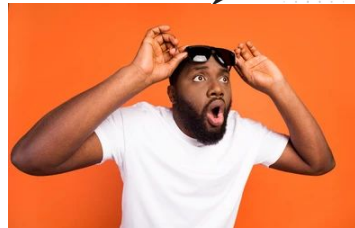
CONTAINER ID	IMAGE	COMMAND	CREATED	STATUS	PORTS	NAMES
a36ad8e57f0a	ubuntu:jammy	"bash"	15 minutes ago	Up 15 minutes		<b>elated_haslett</b>

```
docker exec a36ad8e57f0a echo "toto"
```

toto

```
docker exec elated_haslett echo "coucou"
```

coucou



# Bind mounts



```
docker run --rm -v HOST:DOCKER_PATH my_docker_conda

mkdir -p fastqc_results
docker run --rm -v $(pwd)/fastqc_results:/course/results/fastqc my_docker_conda

## /course/results/ is created by run_qc.sh
```

```
docker run --rm -v HOST:DOCKER_PATH my_docker_conda
```

You can enter into the container and modify script *run\_qc.sh* and run it

*BUT*

*modifications in run\_qc.sh are not saved when you exit*

```
docker run -it --rm -v $(pwd):/course/ my_docker_conda /bin/bash
```



# Distributing your images

[Docker Hub](#)

[Quay](#)

[Biocontainers](#)

[Rocker](#)

[Jupyter containers](#)

register into `https://hub.docker.com/`



# Distributing your images

```
# login you (once)
docker login -u your_dockerhub_id
# build image:1.3.0 can be pushed into dockerhub
# ... run it
docker run -it image:1.3.0
# and recovery image_ID (fd8a0825c9c9 in this example)
docker ps
# commit !
docker commit -m "First push" -a "Julie Orjuela" fd8a0825c9c9
your_dockerhub_id/image:1.3.0
# and push
docker push your_dockerhub_id/image:1.3.0
# Now image can be download/pull for collaborators from dockerhub
docker pull your_dockerhub_id/image:1.3.0
```



# Packaging the case study

MRSA case

Multiresistant bacteria MRSA. Here we will build and run a Docker container that contains all the work we've done so far.

- We've [set up a GitHub repository](#) for version control and for hosting our project.
- We've defined a [Conda environment](#) that specifies the packages we're depending on in the project.
- We've constructed a [Snakemake workflow](#) that performs the data analysis and keeps track of files and parameters.
- We've written a [R Markdown document](#) that takes the results from the Snakemake workflow and summarizes them in a report

```
# explore it :
```

```
ls training_reproducible_research/tutorials/containers
```

```
drwxrwxr-x 2 orjuela orjuela 4096 juin    5 10:34 code  
-rw-rw-r-- 1 orjuela orjuela 1569 juin    5 10:34 config.yml  
-rw-rw-r-- 1 orjuela orjuela 2292 juin    5 10:34 Dockerfile  
-rw-rw-r-- 1 orjuela orjuela 1824 juin    5 10:34 Dockerfile_slim  
-rw-rw-r-- 1 orjuela orjuela  515 juin    5 10:34 environment.yml  
-rw-rw-r-- 1 orjuela orjuela  765 juin    5 10:34 run_qc.sh  
-rw-rw-r-- 1 orjuela orjuela 6577 juin    5 10:34 Snakefile
```

```
# Look the Dockerfile
```

```
it install the conda packages listed in environment.yml
```

```
CMD => it will run the whole Snakemake workflow
```

```
# Build it
```

```
docker build -t my_docker_project -f Dockerfile .
```



```
# OR pull it if they are in dockerhub
```

```
docker pull nbisweden/workshop-reproducible-research
```

```
# Validate
```

```
docker image ls
```

```
# Reproduce your analysis workflow
```

```
docker run -it -p 8888:8888
```

```
nbisweden/workshop-reproducible-research \  
jupyter notebook --ip=0.0.0.0 --allow-root
```



Singularity

# Singularity Nomenclature

A **Singularity definition file (.def)** is a recipe used to build a Singularity image

A **Singularity image (.sif)** is the builded container

# Singularity Nomenclature

	Docker	Singularity
Base	<b>FROM</b> ubuntu:16.04	<b>Bootstrap:</b> docker <b>From:</b> ubuntu:16.04
people	<b>MAINTAINER</b> "John Sundh" john.sundh@scilifelab.se	
description	<b>LABEL</b> description = "Minimal image for the NBIS reproducible research course."	<b>%labels</b> "Minimal image for the NBIS reproducible research course."
workdir	<b>WORKDIR</b> /course	<b>%post</b> mkdir /course cd /course

# Singularity Nomenclature

	Docker	Singularity
Installations	<b>RUN</b> apt-get update && \ apt-get install -y --no-install-recommends bzip2 \ ca-certificates \ curl \ [...] \ vim \  && apt-get clean	<b>%post</b> apt-get update -y && \ apt-get install -y --no-install-recommends bzip2 \ ca-certificates \ curl \ [...] \ vim \  && apt-get clean -y
set environment	<b>ENV</b> PATH="/usr/miniconda3/bin:\${PATH}" <b>ENV</b> LC_ALL en_US.UTF-8 <b>ENV</b> LC_LANG en_US.UTF-8	<b>%environment</b> PATH="/usr/miniconda3/bin:\$PATH" LC_ALL=en_US.UTF-8 LC_LANG=en_US.UTF-8
execution	<b>CMD</b> /bin/bash	<b>%startscript</b> /bin/bash

# Singularity commands

# Build a container

```
singularity build Singularity.sif Singularity.def
```

# Run a command from a container:

```
singularity run Singularity.sif echo toto
```

# Use a container interactively:

```
singularity shell Singularity.sif
```

#Get a singularity container from a docker image:

```
singularity pull mrsa_proj.sif  
docker://nbisweden/workshop-reproducible-research
```





# What/where to use ?

	Docker	Singularity
Limitations	<p>To maintain the Docker engine, Docker daemon needs to be run in the background</p> <p>Docker daemon needs <u>root privileges</u>, which could potentially be a security concern.</p>	<p>Smaller community</p> <p>Not good for windows (a lot of dependencies needed)</p>
Strengths	<p>Docker is suitable for DevOps engineering</p> <p>Docker Hub provides a great number of pre-built Docker images, which is convenient to meet the needs of many applications.</p> <p>Big community</p> <p>Containers strictly isolated from the system</p>	<p>More <u>suitable for scientific users</u></p> <p>Singularity containers are preferred when running applications in <u>HPC systems</u>.</p> <p>Singularity containers can be run without sudo. Unprivileged users can also use <code>--remote</code> or <code>--fakeroot</code> features to build Singularity containers.</p> <p>Singularity can convert Docker containers to Singularity</p>

# Warning!

Une image permet de faire de la reproductibilité **MAIS** un fichier de définition n'est pas forcément reproductible.

Si les versions ne sont pas fixées dans le fichier de définition, l'image reconstruite plusieurs mois/années plus tard sera différente.

En 1955:  
Citroën DS:latest



En 2019:  
Citroën DS:latest



En 2023:  
Citroën DS:1955

