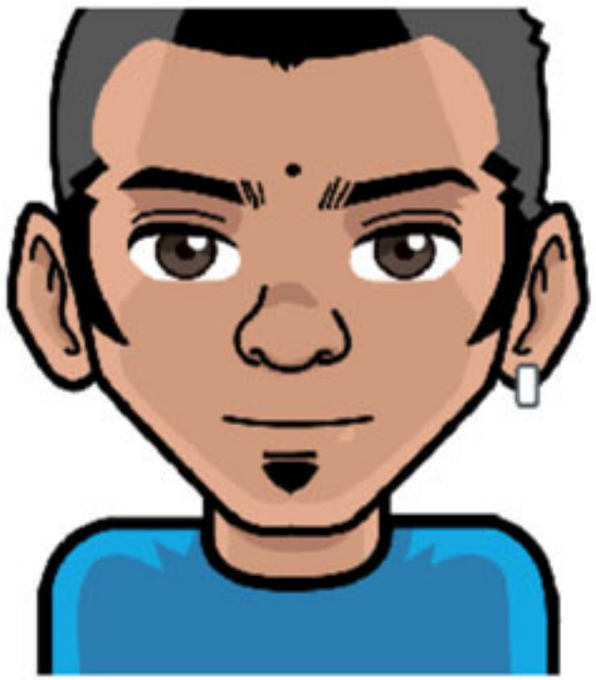
Raju Gandhi

HANDS-ON DOCKER

Learn best practices for building maintainable Dockerfiles

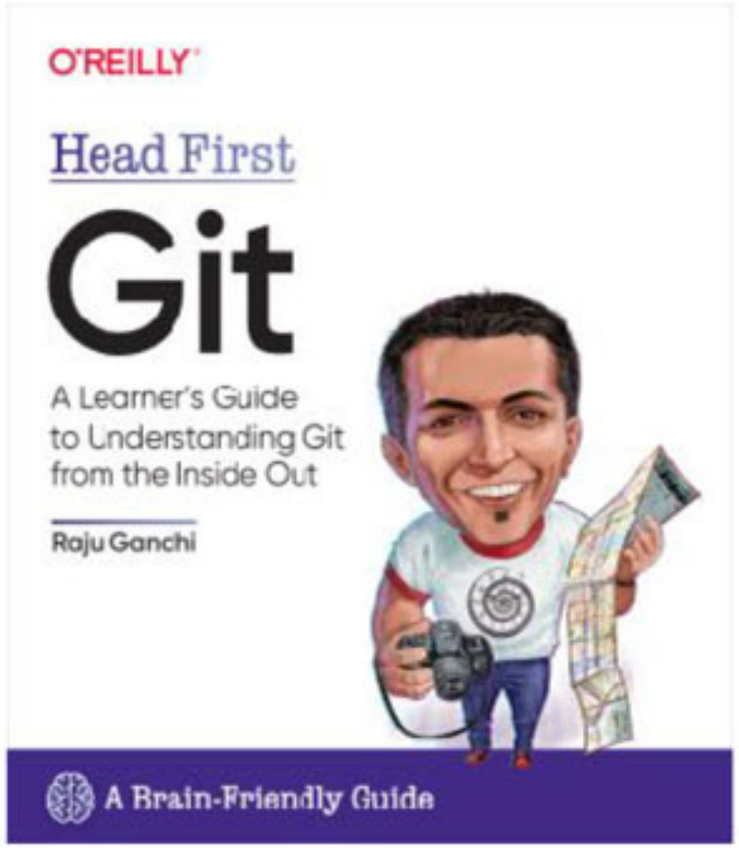


RAJU GANDHI

RAA-JEW ('A' LIKE THE 'A' IN CAR)

@LOOSELYTYPED

FOUNDER - DEFMACRO SOFTWARE



https://i-love-git.com

https://learning.oreilly.com/library/view/head-first-git/9781492092506/

WHY?

BUILD ONCE, RUN ANYWHERE

WE WANT ...

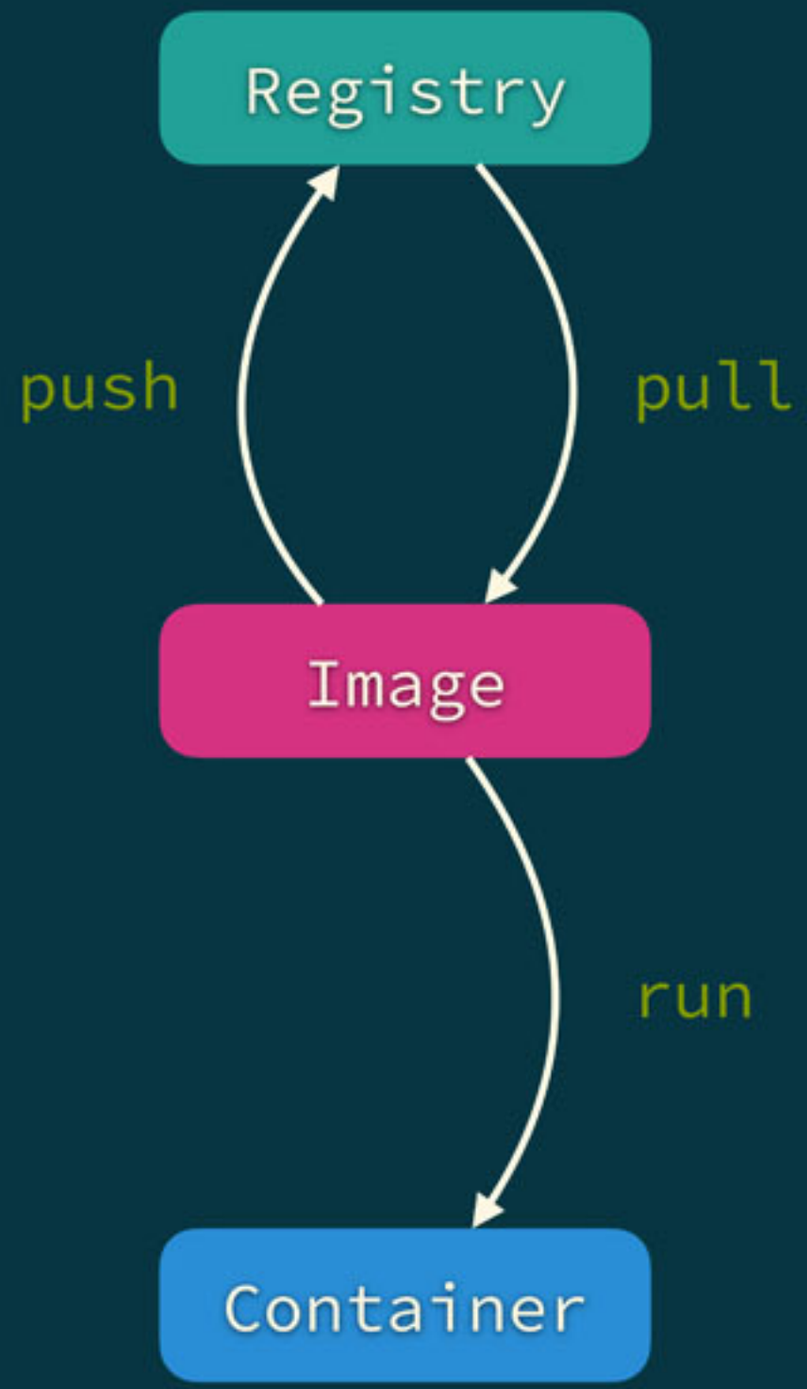
FASTER BUILDS

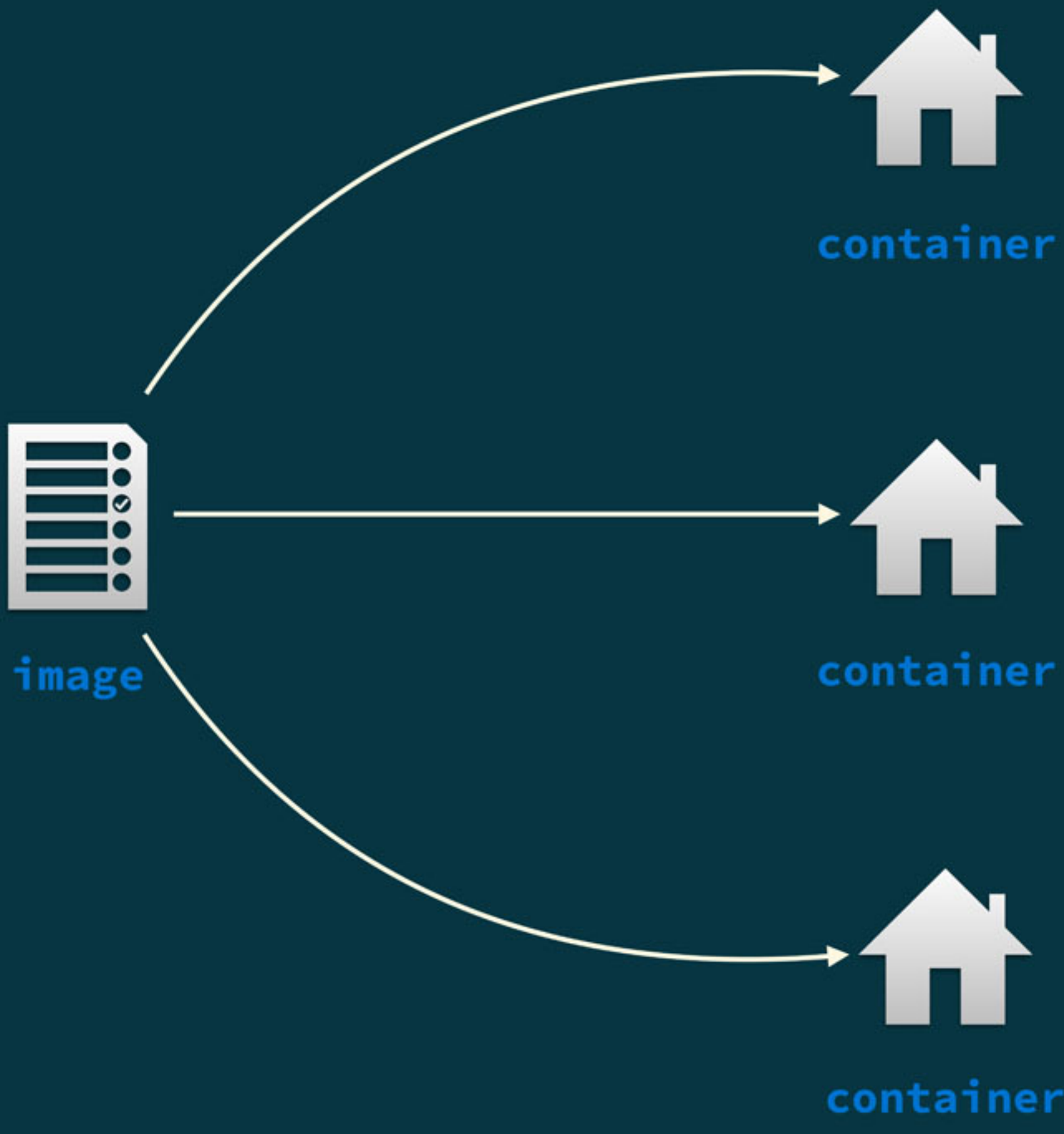
LEANER IMAGES

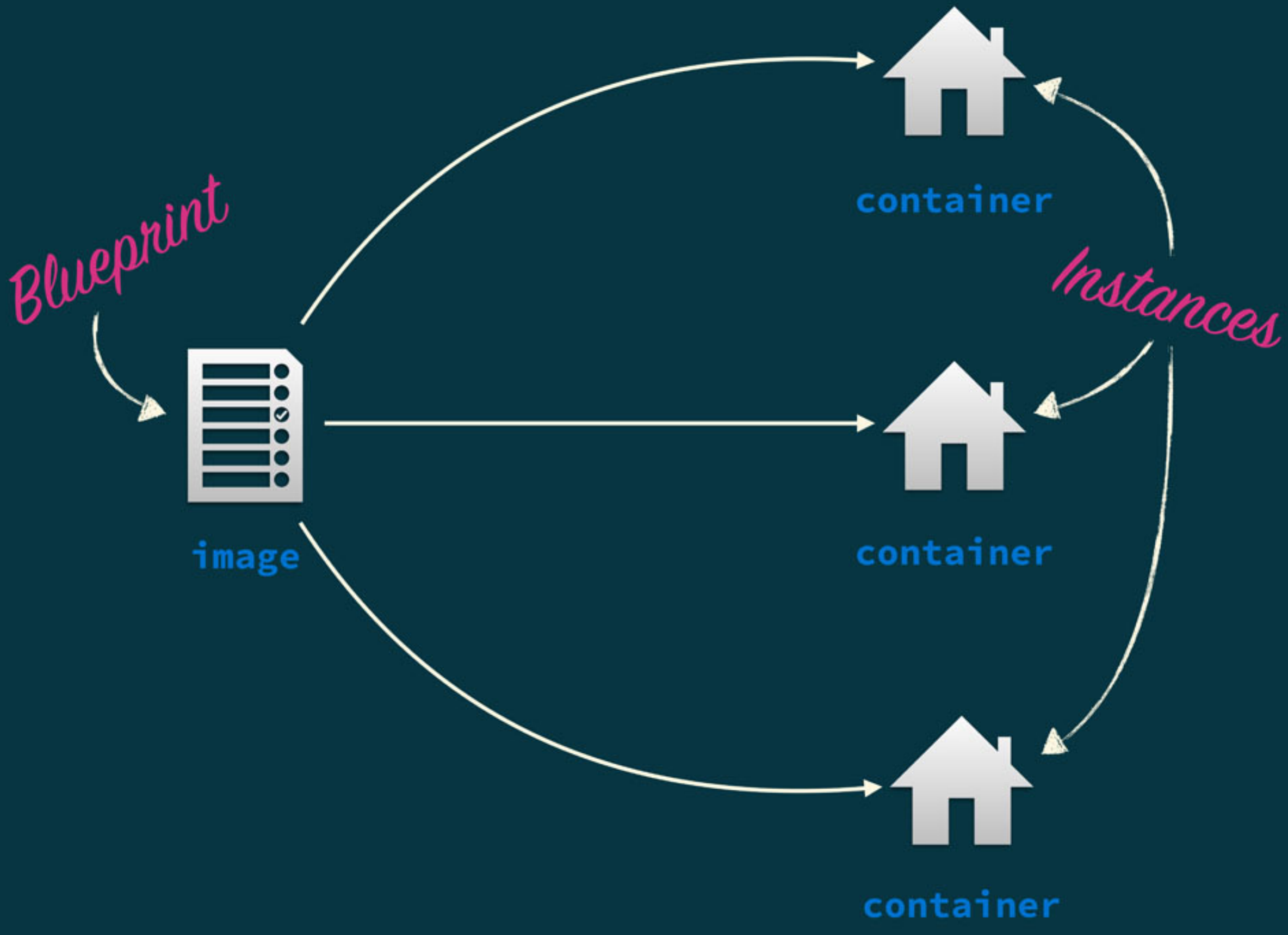
DETERMINISTIC BUILDS

FLEXIBLE RUNTIME

IMAGES


Registry
push
pull
Image
run
Container


container
image
container
container


Blueprint
container
Instances
image
container
container

IMAGES AS "CLASSES"

IMAGES

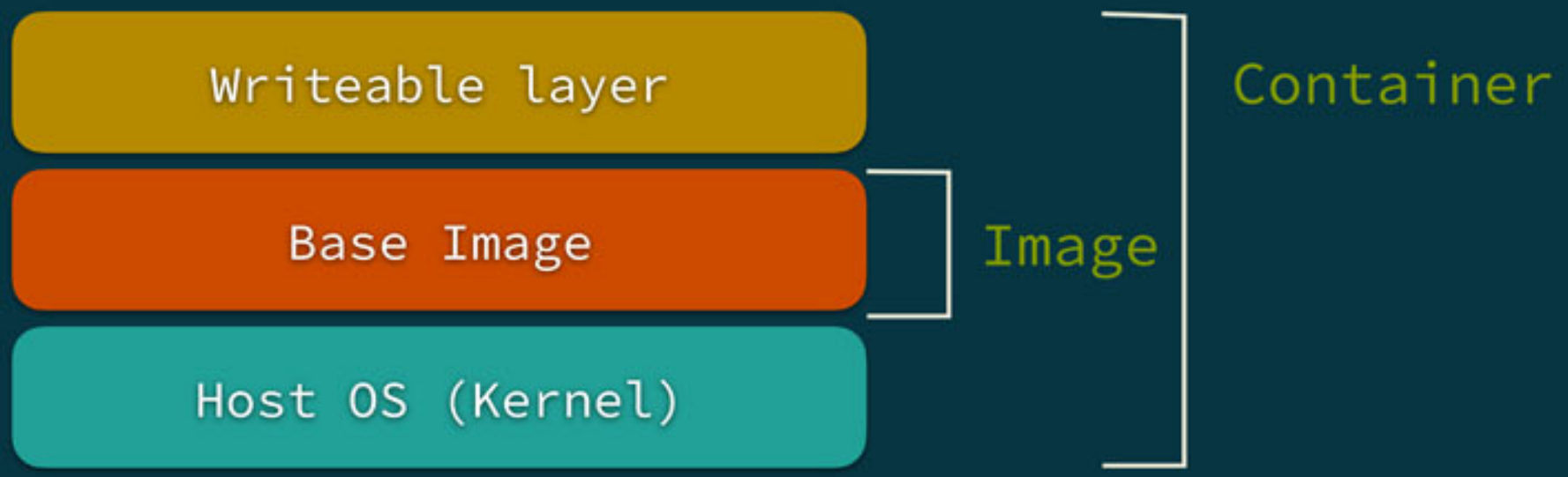
- The docker artifact
- Opaque
- Shared using a registry like http://hub.docker.com/

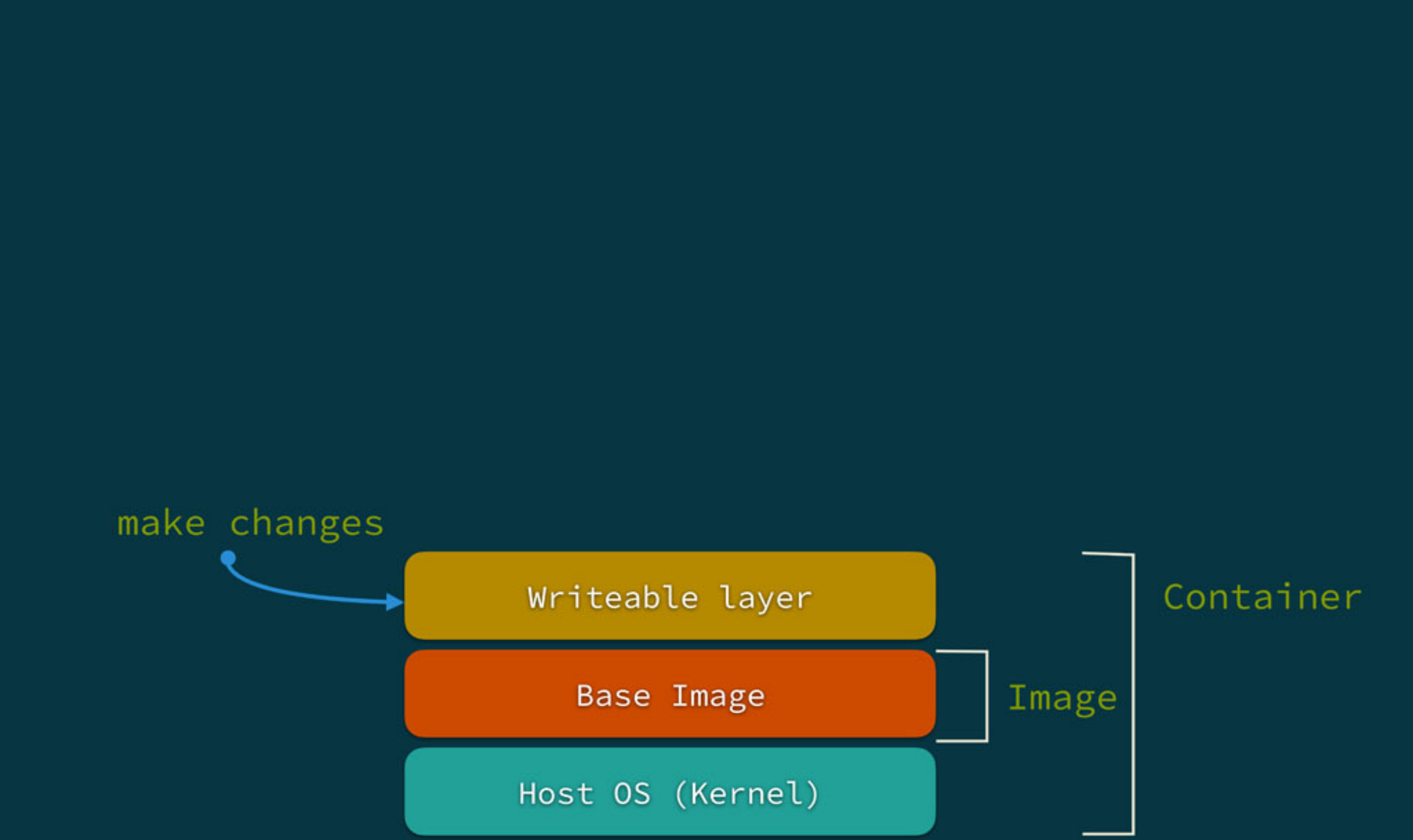
CONTAINERS AND COPY-ON-WRITE

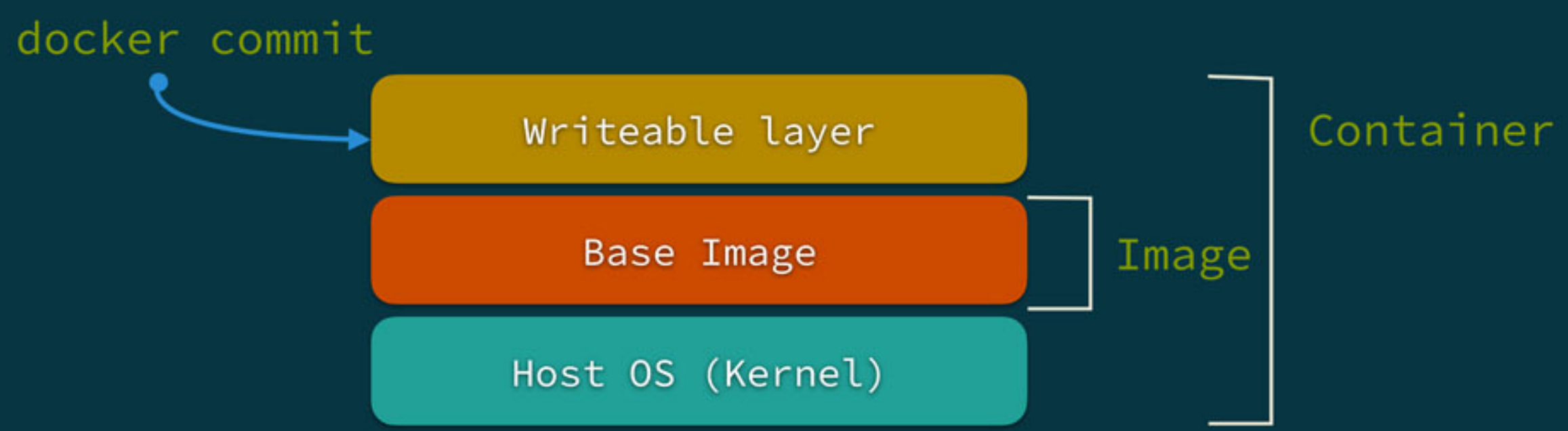
WHAT IS A CONTAINER

- An instance of an image
- With a r/w layer on top
- Configured with resource limits (cpu/memory), network settings and volume mounts etc on "create"

```
docker run
```


Writeable layer
Base Image
Host OS (Kernel)
Image
Container

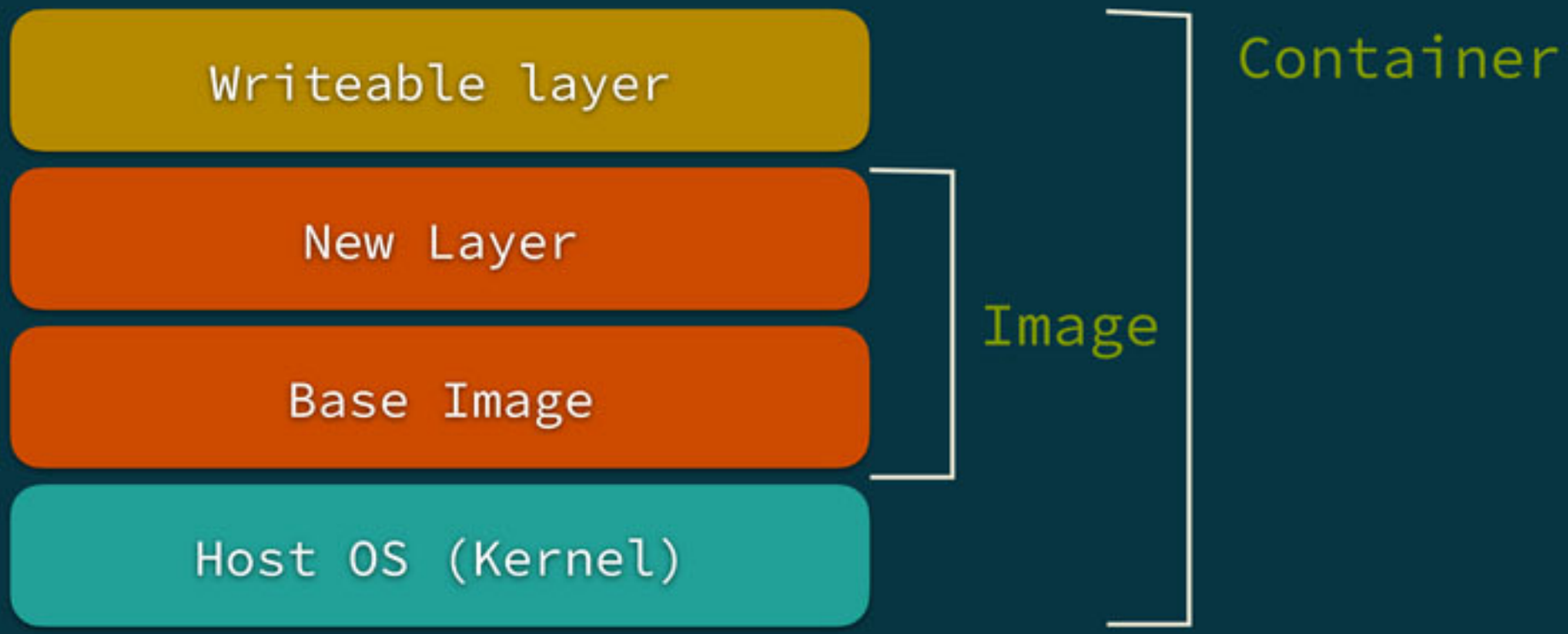

make changes
Writeable layer
Base Image
Host OS (Kernel)
Image
Container

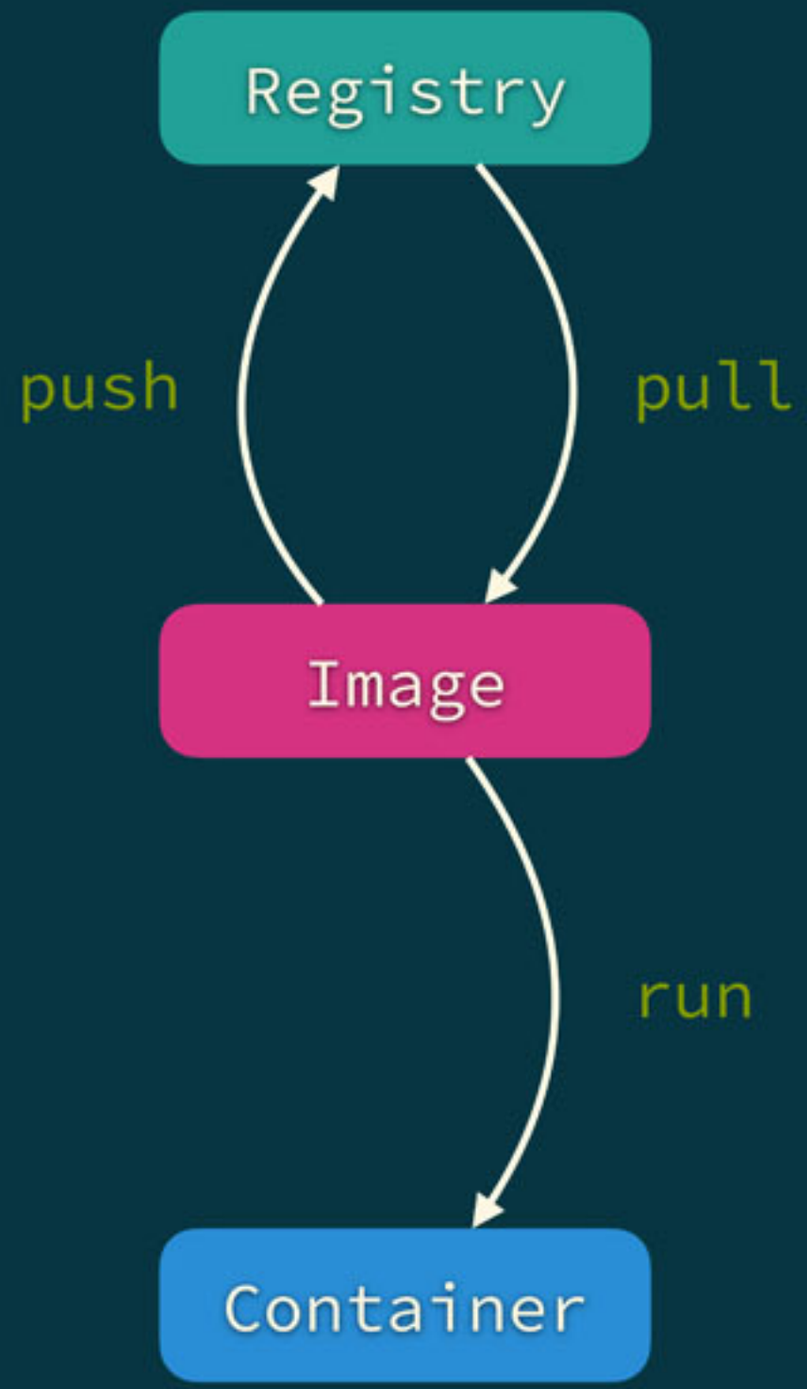

docker commit
Writeable layer
Base Image
Host OS (Kernel)
Image
Container

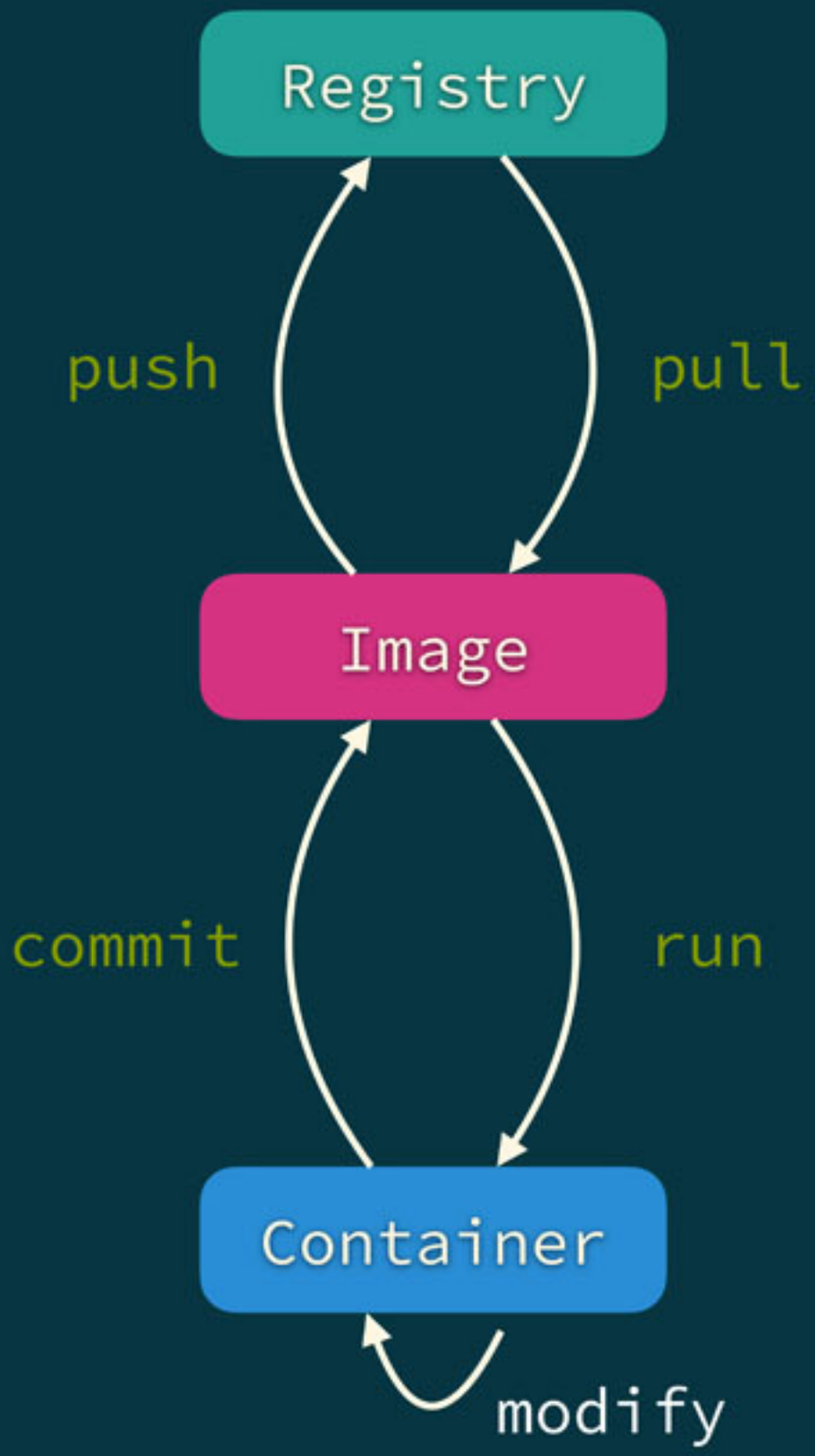

New Layer
Base Image
Host OS (Kernel)
Image


New Layer
Base Image
Host OS (Kernel)
UFS
Image

docker run


Writeable layer
New Layer
Base Image
Host OS (Kernel)
Container
Image


Registry
push
pull
Image
run
Container


Registry
push
pull
Image
commit
run
Container
modify

IF I CAN DO THIS USING COMMANDS, WHY DO WE NEED DOCKERFILES?

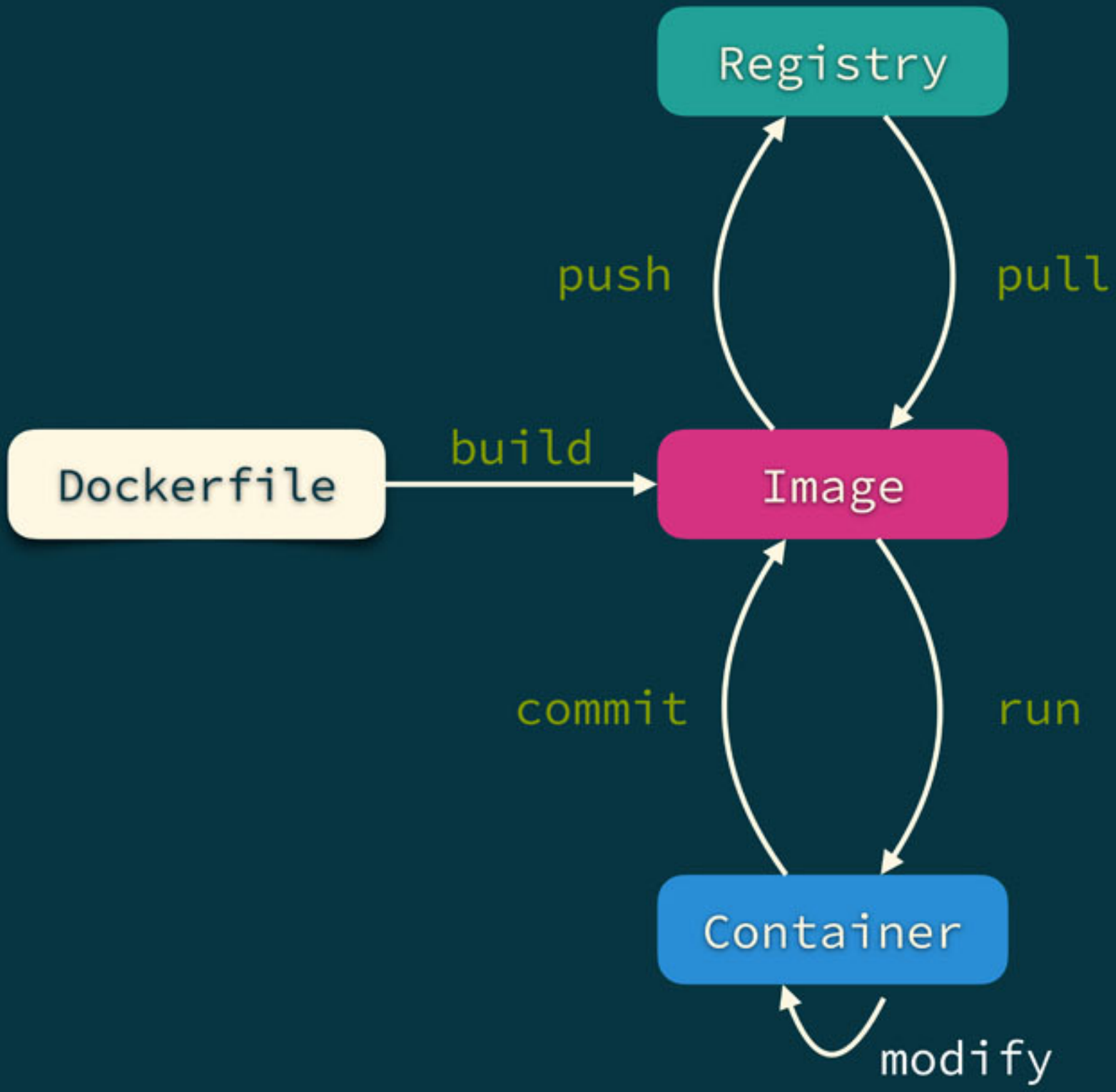
@EXERCISE

EXERCISE

- Start a container with a unique name using ubuntu:22.04
  - Modify the container in some way — install something or touch some files
- Stop the container, and use "docker container commit" to create a new image
- Start a new container from the newly created image
  - Check to see if your changes are still around

HINTS

- To install on ubuntu use "apt update -y && apt install git"
- To create a file you can use "touch <filename>"
- Look up "docker help container" and "docker container commit --help"


Registry
push
pull
Dockerfile
build
Image
commit
run
Container
modify

DOCKERFILE

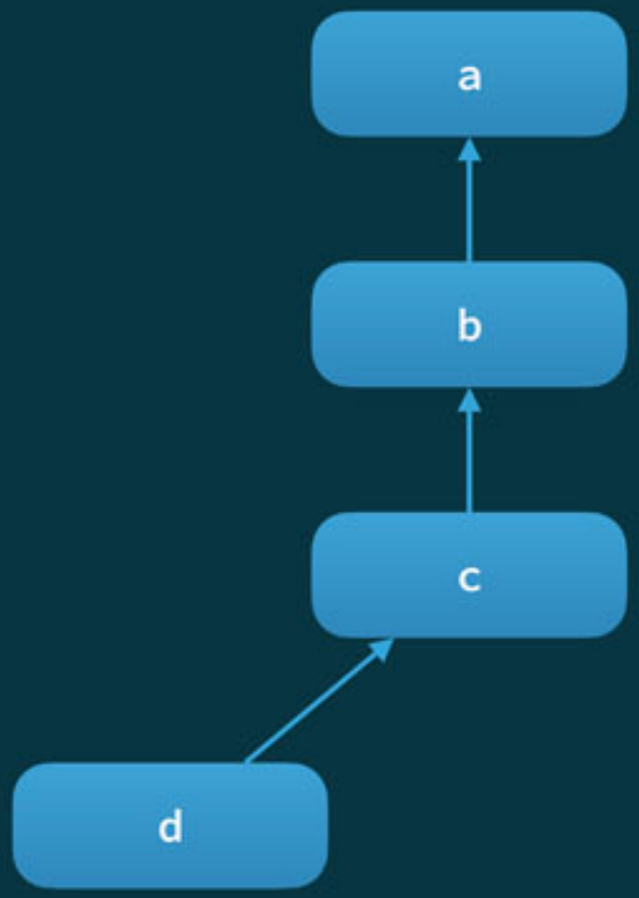
DOCKERFILES

- A set of instructions to build a Docker image
- Plain text, version controlled
- Provides insight into the container needs/capabilities/ intents

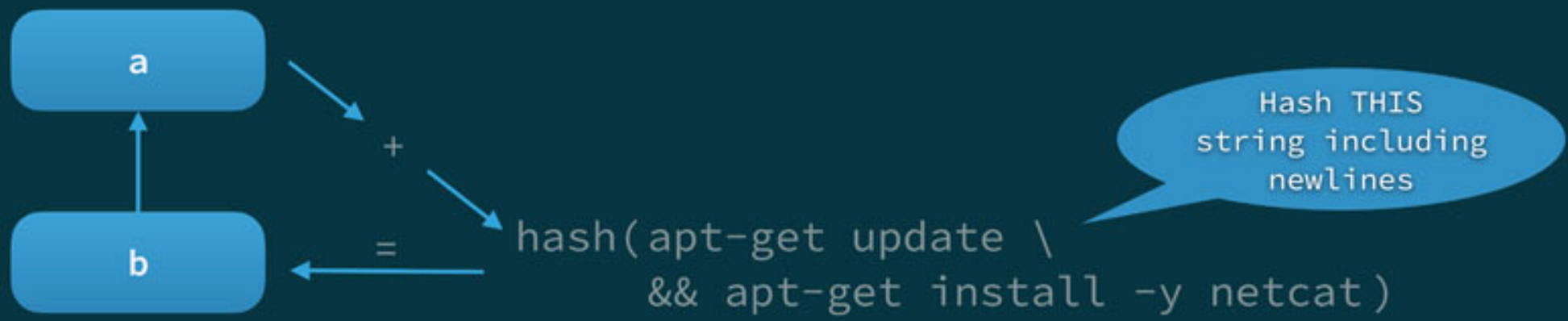
```
# sample Dockerfile
FROM openjdk:8u131-jre

RUN apt-get update \
  && apt-get install -y netcat

COPY build/libs/app-fat.jar /var/app.jar

CMD ["java", "-jar", "/var/app.jar"]
```

UNION FILE SYSTEM

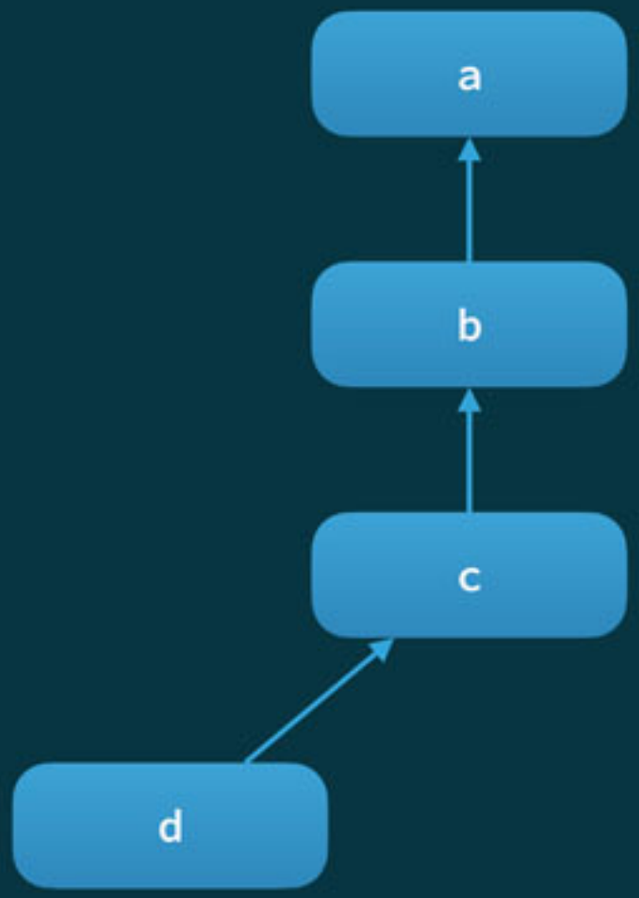
```
# sample Dockerfile
FROM openjdk:8u131-jre

RUN apt-get update \
  && apt-get install -y netcat

COPY build/libs/app-fat.jar /var/app.jar

CMD ["java", "-jar", "/var/app.jar"]
```



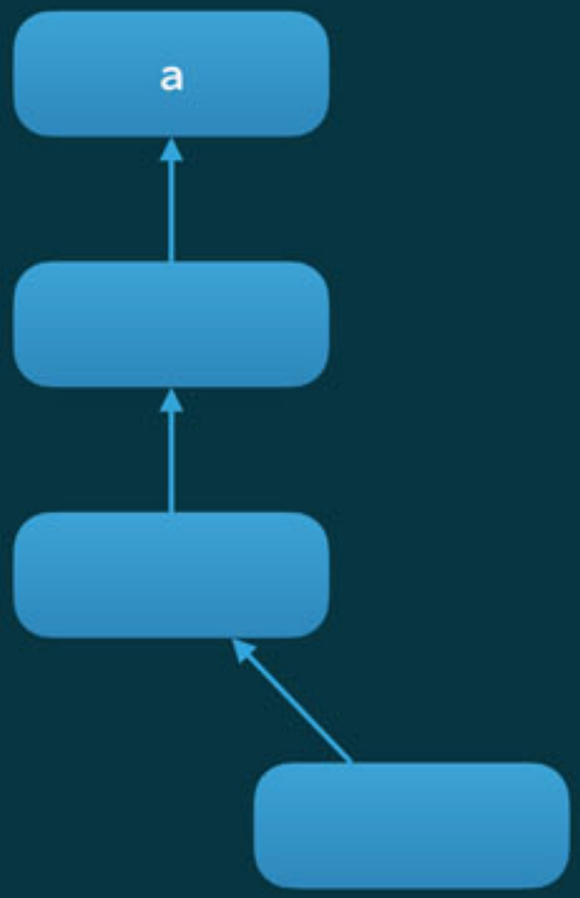

```
FROM openjdk:8u131-jre


RUN apt-get update \
    && apt-get install -y netcat

COPY build/libs/app-fat.jar /var/app.jar


CMD ["java", "-jar", "/var/app.jar"]
```


a
b
+
=
hash(apt-get update \
&& apt-get install -y netcat)
Hash THIS
string including
newlines

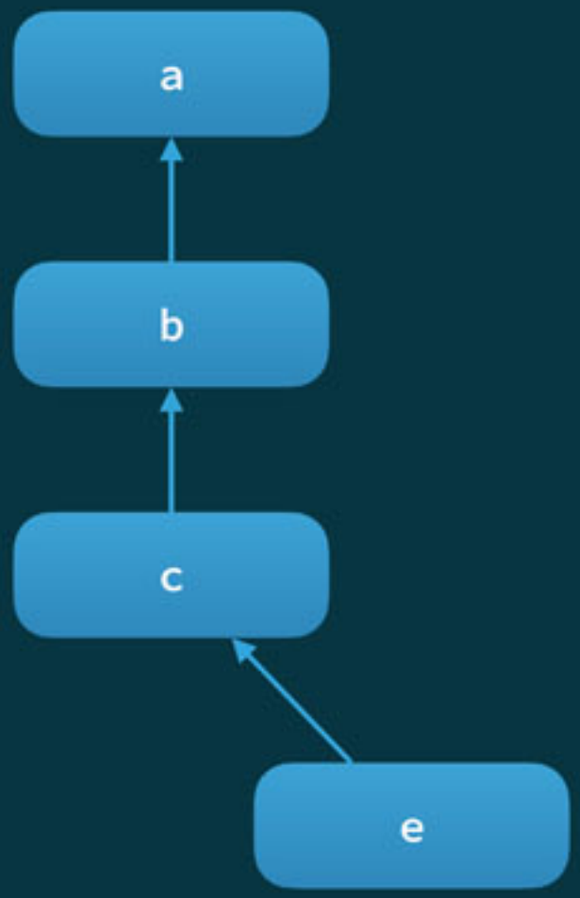

a
b
c
+
=
+
=
openjdk:8u131-jre
hash(apt-get update \
&& apt-get install -y netcat)
Hash THIS
string including
newlines
hash(build/libs/app-fat.jar /var/app.jar)
For COPY/ADD
its the hash of the file
contents
["java", "-jar", "/var/app.jar"]



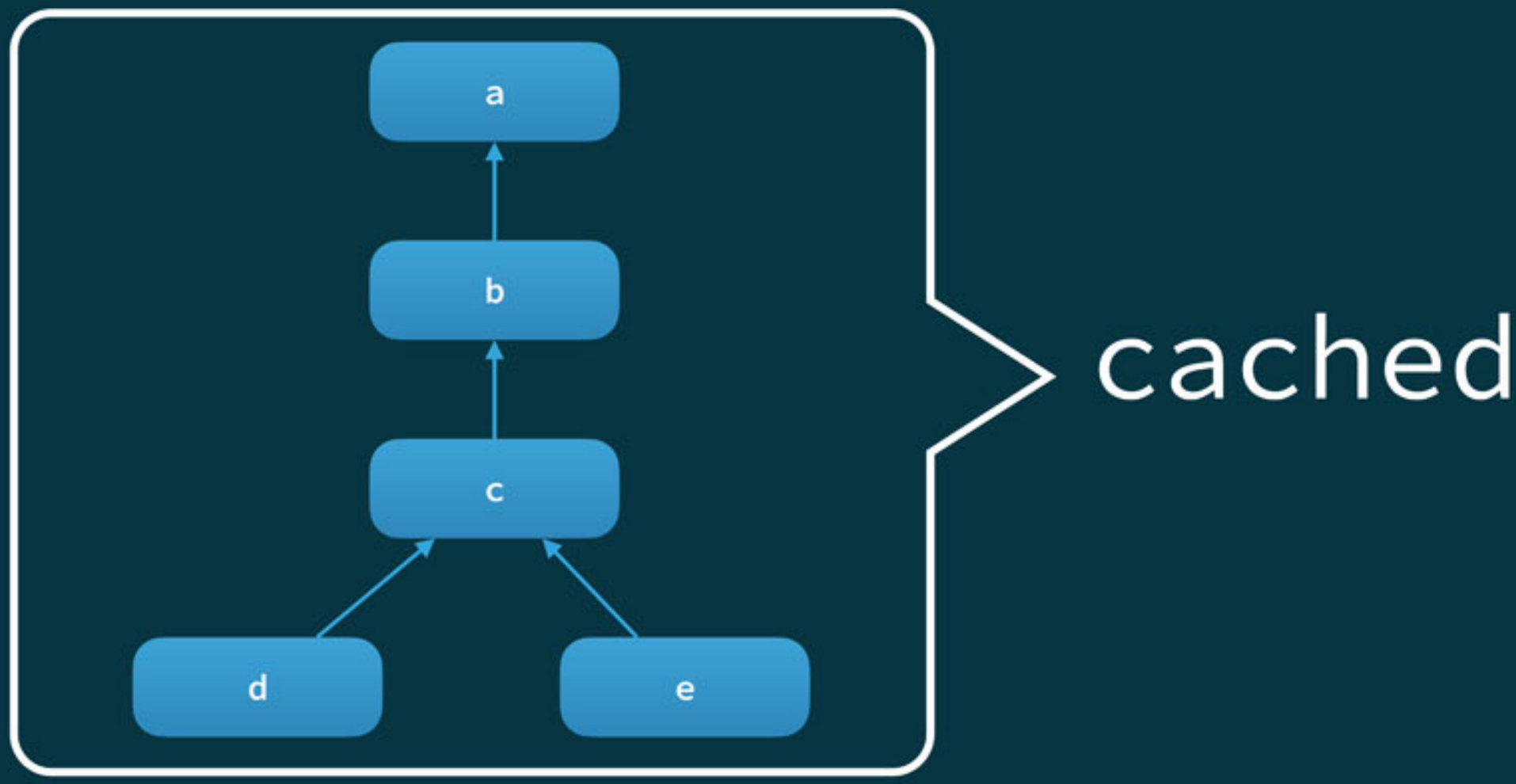

```
FROM openjdk:8u131-jre


RUN apt-get update \
    && apt-get install -y netcat

COPY build/libs/app-fat.jar /var/app.jar


CMD ["java", "-jar", "/var/app.jar"]
```




```
FROM openjdk:8u131-jre


RUN apt-get update \
    && apt-get install -y netcat


COPY build/libs/app-fat.jar /var/app.jar


CMD ["ls", "-al"]
```




```
FROM openjdk:8u131-jre


RUN apt-get update \
    && apt-get install -y netcat


COPY build/libs/app-fat.jar /var/app.jar


CMD ["ls", “-al"]
```


a
b
c
d
e
cached

@EXERCISE

EXERCISE

- Start with a simple Dockerfile – You can use one from your projects or use the "Dockerfile" in the repo you cloned for this workshop
- Build it, and pay attention to what "docker build" is doing
  - Then build it again to see if the cache kicks in
- Make some changes to the Dockerfile – reformat the file, introduce some white space, and see what causes the cache to be invalidated

HINTS

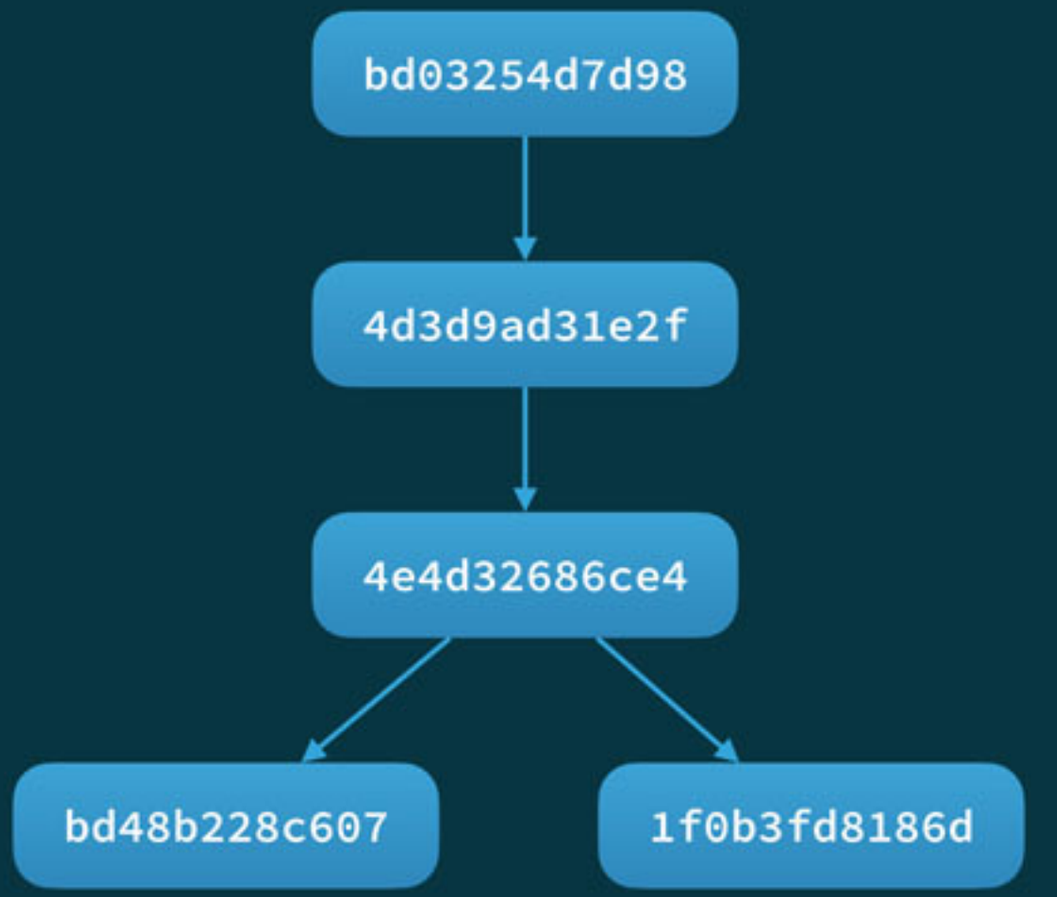
- export DOCKER_BUILDKIT=0
- There are many files in the repository you cloned. Use the one named "Dockerfile" if you want something to play with
- Try changing "RUN apt-get update" to "RUN apt-get update" (double space after "RUN" and "RUN apt-get update" (double space after apt-get)

```
#!/usr/bin/env bash

last=alpine:3.8
for i in `seq 200`; do
  rm -f cid
  docker run --cidfile=cid $last touch file$i;
  docker commit `cat cid` tag$i;
  docker rm `cat cid`;
  last=tag$i;
done
```

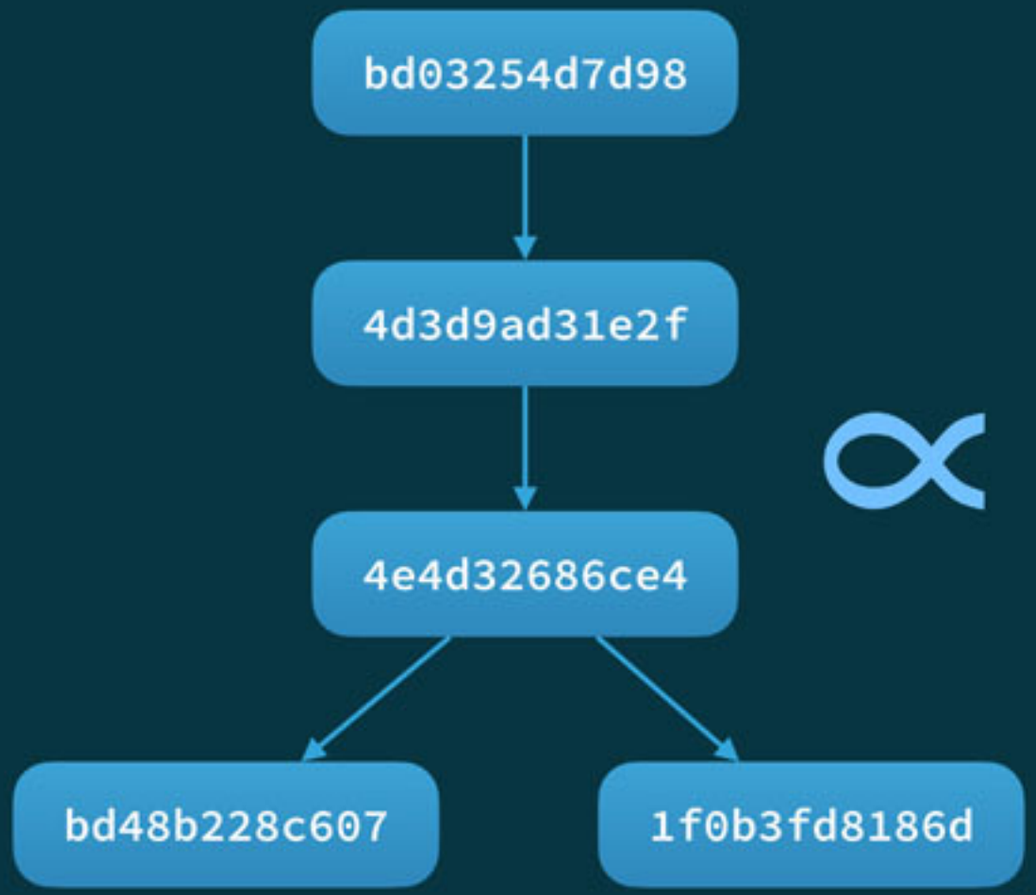
```
#!/usr/bin/env bash

last=alpine:3.8
for i in `seq 200`; do
  rm -f cid
  docker run --cidfile=cid $last touch file$i;
  docker commit `cat cid` tag$i;
  docker rm `cat cid`;
  last=tag$i;
done

# Error response from daemon: max depth exceeded
# Unable to find image 'tag125:latest' locally
```

```
FROM alpine:3.8

RUN touch file1
RUN touch file2
# 125 times more
RUN touch file127
```

```
FROM alpine:3.8

RUN touch file1
RUN touch file2
# 125 times more
RUN touch file127

# Error response from daemon: max depth exceeded
```




```
FROM openjdk:8u131-jre

RUN apt-get update \
    && apt-get install -y netcat

COPY build/libs/app-fat.jar /var/app.jar

CMD ...
```




```
FROM openjdk:8u131-jre

RUN apt-get update \
    && apt-get install -y netcat

COPY build/libs/app-fat.jar /var/app.jar

CMD ...
```

ONE CONCERN PER CONTAINER

@LOOSELYTYPED

THE THREE AMIGOS (SORTA)

- Build-time
  - FROM, ARG, RUN, ADD/COPY, USER
- Run-time
  - ENV, ENTRYPOINT/CMD, HEALTHCHECK
- Meta-data
  - LABEL, EXPOSE

FROM

NOTES

- Implies “ancestry”
- **Has** to be the first line (Except if preceded by `ARG`)
- Has implications on `WORKDIR`, `USER`, `ENTRYPOINT` (and `CMD`), and `ONBUILD`, `EXPOSE` and other commands
  - Use "`docker inspect`" for this
- Has **HUGE** implications on the final size of your image
- Create a base image with `FROM scratch`

DO'S

- Pin down the exact tag (or even better the digest)
  - Do not use "latest" tag
- Choose your parent image wisely
  - Vet it!
    - Inspect ancestor images for `USER`s, `PORT`s, `ENV`s, `VOLUME`s, `LABEL`s and anything that can be inherited
- Most likely you will build the lineage yourself internal to your team and organization

```
# Don't
FROM alpine

# Do
# Pin the version
FROM alpine:3.8
# OR Use ARG to set it at build time
ARG version=3.8
FROM alpine:${version}
```

@EXERCISE

EXERCISE

- Start with a Dockerfile (If you don't have one, then use Dockerfile in the repository you cloned)
  - Build it without supplying a version – Inspect "docker image ls <image-name>" and ensure it has the latest tag
  - Make a change to the Dockerfile and now **build it with a version.** Inspect "docker image ls <image-name>"
    - Is the "latest" really the latest?
- Why is FROM a "build time" instruction?

HINTS

- docker build -t demo -f Dockerfile . # build an image with "latest"
- docker build -t demo:1.1.1 -f Dockerfile . # build with a version

ARG

DO'S

- Use `ARG` for configuring image construction at build times
- Use `ARG`s to supply dynamic parameters to `FROM`, `ENV`, `LABEL` and `RUN`
- Default them appropriately

```
# Do
# Use default value
ARG AUTHOR="Raju Gandhi"
ARG BUILD_DATE
ARG VCS_REF
```

```
# default author
docker build -t test .
# set at build time
docker build --build-arg AUTHOR="Solomon Hykes" -t test .
```

@EXERCISE

EXERCISE

- Start with the following Dockerfile (Use Dockerfile.sample)

```
FROM alpine:3.12
RUN cat /etc/alpine-release
```

  - Introduce a VERSION ARG (with a default of 3.9) and use it in the FROM instruction
  - Build the image twice, once with defaults, and once supplying it with an build arg (of 3.9)
    - Pay attention to which step invalidates the cache
- Why is ARG a "build time" instruction?

HINTS

- ARG SOME_ARG=VALUE
- To use an ARG use ${SOME_ARG} syntax
- docker help build

RUN

DON'TS

- Do not do OS level upgrades (eg. `RUN dist-upgrade`)

DOS

- Be cognizant of the effects (and drawbacks) of caching
- Group logical operations
    - Clean up as well (reduces image sizes) after installing libraries, unzipping tarballs etc
- Use multiline (\) to make PR / auditing easier
    - Or use the newer "heredoc" syntax (Currently experimental)

```
# Don't
RUN apt-get update
RUN apt-get install -y netcat=1.217-3ubuntu1
RUN apt-get clean

# Do
RUN apt-get update \
  && apt-get install -y --no-install-recommends \
  netcat=1.217-3ubuntu1  \
  && apt-get clean \
  && rm -rf /var/lib/apt/lists/*
```

@QUIZ

EXERCISE

- Why SHOULDN'T you do this?

```
RUN apt-get update \
  && apt-get install -y --no-install-recommends \
  netcat=1.217-3ubuntu1
```

```
RUN apt-get clean \
  && rm -rf /var/lib/apt/lists/*
```

@EXERCISE

EXERCISE

- Start with the following Dockerfile (Use Dockerfile.sample)

```
FROM fedora:33
RUN dnf install -y git
```

  - Build this image and inspect it's size
  - Follow the instructions in https://www.redhat.com/sysadmin/tiny-containers (Step 1) to clean up after installation
  - Build the image again, and compare the two sizes
- Why is RUN a "build time" instruction?

HINTS

- docker image ls <image_name>

```
# syntax=docker/dockerfile:1.4

# sample Dockerfile
FROM ubuntu:21.10

RUN <<EOF
apt-get update
apt-get install -y --no-install-recommends \
  netcat=1.217-3ubuntu1
apt-get clean
rm -rf /var/lib/apt/lists/*
EOF
```

```
# syntax=docker/dockerfile:1.4

# sample Dockerfile
FROM nginx

COPY <<EOF /usr/share/nginx/html/index.html
<!DOCTYPE html>
<html lang="en">
  <head>
    <meta charset="UTF-8">
    <title>Using Heredocs in Docker</title>
  </head>
  <body>
    <h1>What !! </h1>
  </body>
</html>
EOF
```

ADD/COPY

.DOCKERIGNORE

```
# example .dockerignore file
# ignore these folders
.git
build
!build/libs/*.jar # but NOT this

# ignore these files
.project
.gitignore
.dockerignore

# ignore all Docker files
Dockerfile*
docker-compose.yml

# ignore all markdown files (md)
*.md
```

DON'TS

- Avoid `ADD`
- Do not leave “residual” artifacts
- Be wary of using the array syntax
- Do not copy over all source in one fell swoop
  - Copy over source files separately and later on since they change often

DO'S

- Instead of `ADD`
  - Combine `COPY` and `RUN`
  - OR `RUN` with wget/curl/tar/unzip
  - See DO'S under `RUN`
- Leverage the `.dockerignore` file

```
# Don't
# ADD is confusing (unless you want to copy & explode a tar file)
ADD src .
# Avoid the array syntax (if you can)
COPY ["src", "test.sh"]
# Copy over ALL source in one fell swoop
COPY . .
```

@EXERCISE

EXERCISE

- Clear out the .dockerignore file in the repository you cloned
- Using Dockerfile.sample, COPY everything from the root directory into the container
  - Build an image from Dockerfile.sample paying close attention to the build context size and the time it takes to build
- Now put back the contents of the .dockerignore file and repeat the previous exercise – Compare build context sizes and times
- Why are ADD/COPY "run-time" instructions?

HINTS

- It's often a good idea to create a WORKDIR – See Dockerfile.multi for an example
- Use COPY . . to copy everything
- In bash you can time a command by using "time docker build ..."

USER

DON'TS

- Do not switch USER often
- Avoid using root

DO'S

- Create a user (if you can) for your service
- Default the container to a non-root user if you can

```
FROM ubuntu:21.04

# Do
RUN groupadd -r app \
  && useradd -r -g app appuser
USER appuser
```

ENV

DONT'S

- Put secrets or sensitive information in `ENV` variables
- Override parent image `ENV`'s unless absolutely necessary

DO'S

- Use them for documentation and modifying runtime behavior
  - They are baked in the final image
- Use `docker run <image-name> env`
  - Or `docker inspect`
- Default then appropriately
- Be cognizant of inherited `ENV` variables

```
ARG PROJECT_VERSION
# Do
# Default them if set dynamically
ENV PROJECT_VERSION ${PROJECT_VERSION:-2.3}
```

@EXERCISE

EXERCISE

- Start with the following Dockerfile (Use Dockerfile.sample)

```
FROM alpine:3.12
```

  - Introduce a few ARGs, and a few ENV
    - Be sure to have at least one ENV use a supplied ARG value
  - Build the image, start a container and ensure that you see the ENVs in the container
- Why is ENV a "run-time" instruction?

HINTS

- To set an ENV to an ARG value use "ENV ENV_NAME ${ARG_NAME}"
- You can inspect the envs in a container using "docker run <image_name> env"

ENTRYPOINT/CMD

NOTES

- `CMD` can be overridden if the user supplies an argument to create or run
    - You can (also) override `ENTRYPOINT` by explicitly supplying `--entrypoint` flag
- The default command run in a container is (`ENTRYPOINT` + `CMD`)

DONT'S

- Avoid the “shell” form

DO'S

- Use the "exec" form
  - Shell expansion will **not** happen!
- Use `ENTRYPOINT` and `CMD` together
- Use a "entrypoint-script"
  - Allows you to set error (-e) flags and traps
  - Your editor is syntax aware
  - Always "exec"

DO'S

- Make the `ENTRYPOINT` be your command
- CMD should be the arguments to the (`ENTRYPOINT`) command
    - This means your consumers simply pass arguments to your command (`docker run image --help`)

```
# Do
# Use ENTRYPOINT and CMD together
ENTRYPOINT [ "echo", "hello" ]
CMD [ "world" ]

# > docker build -t entrypoint-cmd .
# > docker run entrypoint-cmd
# hello world
# > docker run entrypoint-cmd raju
# hello raju
```

```
# Do
COPY entrypoint.sh /usr/local/bin/
ENTRYPOINT ["entrypoint.sh"]
CMD ["default"]


# entrypoint.sh
if [ "$1" = 'default' ]; then
    # do default thing here
    echo "Running default"
    # exec your-default-command
else
    echo "Running user supplied arg"
    # if the user supplied say /bin/bash
    exec "$@"
fi
```

@EXERCISE

EXERCISE

- Start with the following Dockerfile (Use Dockerfile.sample)

```
FROM alpine:3.12
```

  - Introduce an ENTRYPOINT (like "ls") and a CMD (like "bin"). Then build an image using this Dockerfile
    - Start the container with no args and observe the behavior
    - Start another container supplying it an argument (like "etc")
    - Start another container supplying it some random word (like "nfjs")
    - Explain this behavior
- Why is ENTRYPOINT and CMD"run-time" instructions?

HINTS

- Alternatively you can use ENTRYPOINT "echo" and CMD "Hello"

@EXERCISE (BONUS)

EXERCISE

- Inspect 080-Dockerfile.entrypoint.sample in your project repository
  - Can you explain how this works?
  - Can you see any application of this pattern in one of your work projects?

HEALTHCHECK

DONT'S

- Be too aggressive with `--interval` period
  - Especially if the check itself is expensive
- Use external tools (like `curl`) if you can

DO'S

- Use a script that leverages the same runtime as your service
    - For example, if you have a node or go service, write a health check using the same runtime
- Be cognizant of the overhead the health check introduces
- Experiment with combinations of interval/timeout/ retries

```
# Avoid
HEALTHCHECK CMD curl --fail http://localhost:5000/ || exit 1

# Do
COPY healthcheck ./healthcheck
HEALTHCHECK --interval=1s \
  --timeout=1s \
  --start-period=2s \
  --retries=3 CMD [ "/healthcheck" ]
```

LABEL

DONT'S

- Define individual labels separately
- Leak secrets

DO'S

- Use them liberally
- Labels can see ARG variables. Use this!
  - BUILD_NUMBER, GIT_SHA
- Apply a standard convention to avoid conflicts
  - Build tooling on top of the conventions

```
ARG AUTHORS="Raju Gandhi"
ARG BUILD_DATE
ARG VCS_REF

# Don't
# LABEL org.opencontainers.image.authors=$AUTHOR
# LABEL org.opencontainers.image.created=$BUILD_DATE
# LABEL org.opencontainers.image.revision=$VCS_REF

# Do
LABEL org.opencontainers.image.authors=$AUTHORS \
  org.opencontainers.image.created=$BUILD_DATE \
  org.opencontainers.image.revision=$VCS_REF
```

@EXERCISE

EXERCISE

- Look over the "Build-time labels" in http://label-schema.org/rc1/
  - Can you think of any you would add to this list?
- Use "docker inspect" with any image on your computer and see if you can spot the labels?
- How would you categorize the "LABEL" instruction?

EXPOSE

DON'TS

- Avoid "`docker run -P`"

DO'S

- Document the ports your application needs exposed

COMPILE VS RUNTIME

```
FROM alpine:3.8

RUN apk add --update \
  tzdata \
  && rm -rf /var/cache/apk/*

ARG TZ=America/Los_Angeles
RUN ln -snf \
/usr/share/zoneinfo/$TZ \
/etc/localtime && echo $TZ > /etc/timezone
```

```
FROM alpine:3.8

RUN apk add --update \
  tzdata \
  && rm -rf /var/cache/apk/*

ARG TZ=Americal/Los_Angeles
ENV TZ $TZ

COPY entrypoint.sh /usr/local/bin/
ENTRYPOINT ["entrypoint.sh"]
CMD ["default"]

# entrypoint.sh
#!/bin/sh
ln -snf \
  /usr/share/zoneinfo/$TZ \
  /etc/localtime && echo $TZ > /etc/timezone
```

DO'S

- Use a combination of ARG and ENV with ENTRYPOINT/ CMD
    - Allows you to express what is at "compile" time versus "runtime"
- ARG/ENV are important parts of your image and containers API

MULTI-STAGE BUILDS

```
#!/usr/bin/env bash

# ── BUILD/TEST CODE ──────────────────────────────────────────────
# build/test our code
docker build -t build-img -f Dockerfile.build .

# ── CREATE A TEMP DIRECTORY ──────────────────────────────────────
mkdir -p target

# ── GET THE JAR OUT ──────────────────────────────────────────────
# start a temporary container from our "build-img"
# so we can get to its filesystem
docker create --name builder build-img
docker cp builder:/code/build/libs/docker-olp-0.0.1-SNAPSHOT.jar \
./target/

# ── BUILD OUR FINAL IMAGE ────────────────────────────────────────
docker build -t final-img -f Dockerfile.final .
```

build

```
FROM openjdk:8u131-jdk as builder
WORKDIR /code
ADD . ./
RUN ["./gradlew", "shadowJar", "--no-daemon"]
```

run

cp

build

```
FROM openjdk:8u131-jre
RUN apt-get update \
 && apt-get install -y --no-install-recommends \
 netcat  \
 && apt-get clean
COPY docker-workshop-0.0.1-SNAPSHOT-fat.jar \
  /var/app.jar
CMD ["java", "-jar", "/var/app.jar"]
```

NOTES

- Allow you to do everything using docker containers
- Separates build environment from runtime, with the net effect of leaner production images
    - Keep secrets out of production images
    - Image builds are much faster because docker can leverage the cache

```
# ─── Build/Test image ──────────────────────────────────────
# Name the builder image "as builder"
FROM openjdk:11.0.5-jdk as builder

WORKDIR /code
COPY *.gradle gradle.* gradlew ./
COPY gradle ./gradle
RUN ./gradlew build || return 0

COPY src/ src/
RUN ["./gradlew", "-q", "--no-daemon"]

# ─── Final production image ────────────────────────────────
FROM openjdk:11.0.5-jre

COPY --from=builder \
  /code/build/libs/docker-olp-0.0.1-SNAPSHOT.jar \
  /var/docker-olp-0.0.1-SNAPSHOT.jar

COPY entrypoint.sh /usr/local/bin/
ENTRYPOINT ["entrypoint.sh"]
CMD ["default"]
```

```
# ─── Build/Test image ──────────────────────────────
# Name the builder image "as builder"
FROM openjdk:11.0.5-jdk as builder

WORKDIR /code
COPY *.gradle gradle.* gradlew ./
COPY gradle ./gradle
RUN ./gradlew build || return 0

COPY src/ src/
RUN ["./gradlew", "-q", "--no-daemon"]

# ─── Final production image ────────────────────────
FROM openjdk:11.0.5-jre

COPY --from=builder \
  /code/build/libs/docker-olp-0.0.1-SNAPSHOT.jar \
  /var/docker-olp-0.0.1-SNAPSHOT.jar

COPY entrypoint.sh /usr/local/bin/
ENTRYPOINT ["entrypoint.sh"]
CMD ["default"]
```

@EXERCISE

EXERCISE

- Study Dockerfile.multi in your project repository
  - What will you do to improve this? Think along the lines of ARGs, LABELs, additional stages

THANKS!!

RESOURCES

- Best practices for writing Dockerfiles
- Docker Registry V2
- Explaining Docker Image IDs
- Dockerfiles for reference
  - redis
  - Jenkins
  - Postgresql