

Docker for JVM Projects

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About the trainer



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Training Objectives

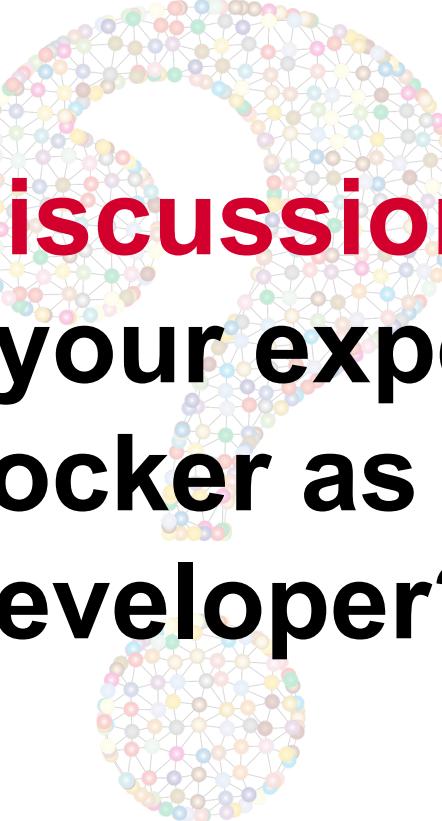
Agenda

- Recap: Docker basics
- Why is Docker important for JVM projects?
- Containerization and distribution of JVM projects
- Resilient, reproducible testing with Docker containers
- Integrating Docker with JVM tooling
- Conclusion & Wrap-up



Introduction

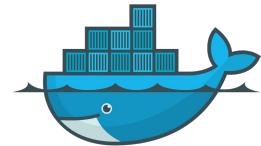
1



Discussion

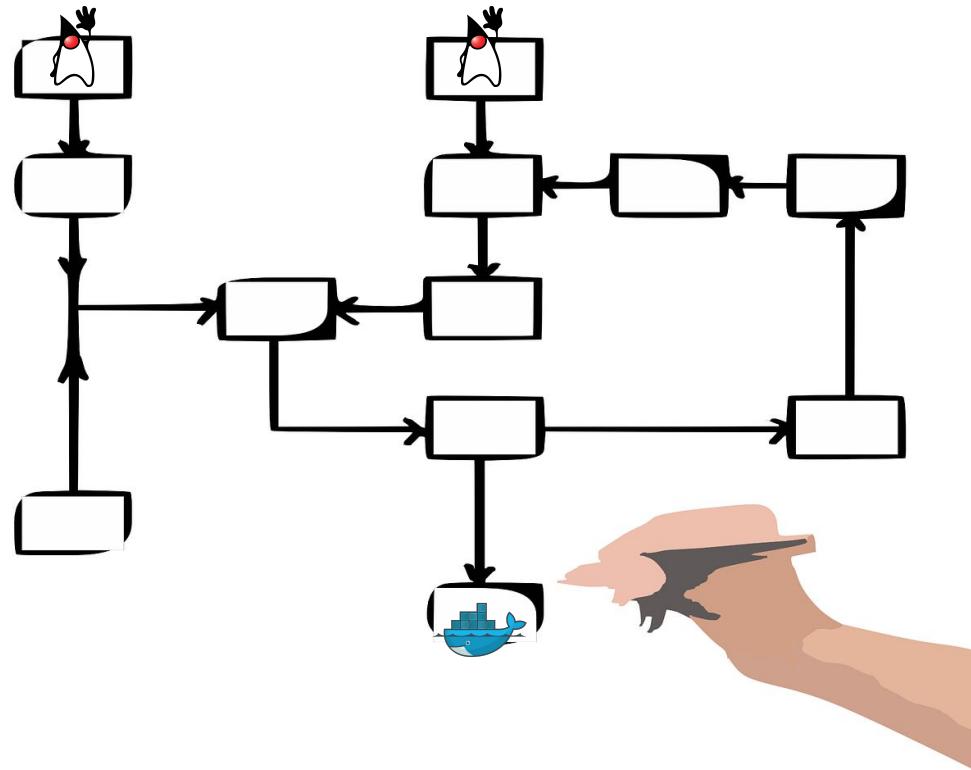
**What's your experience
with Docker as a JVM
developer?**

Docker in a nutshell

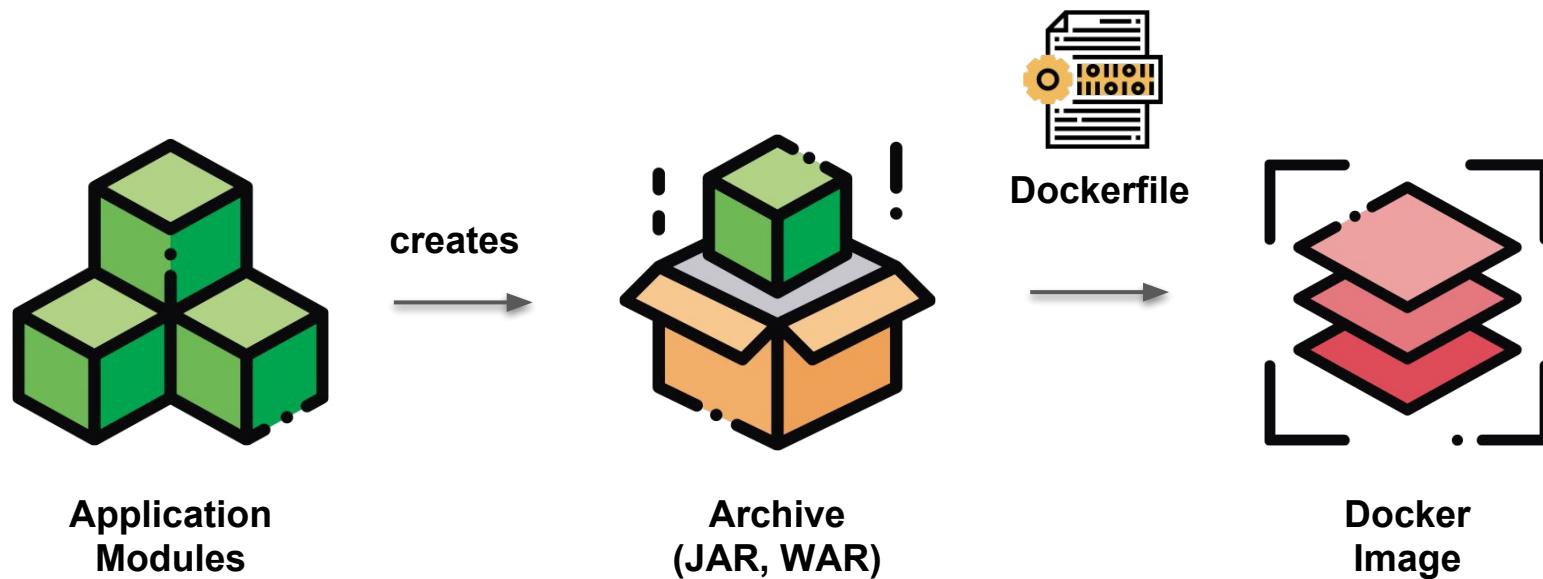


- Lightweight virtualization technology
- Creates, manages and orchestrates containers
- Containers are fast to start and portable
- Docker Engine is infrastructure plumbing software that runs and orchestrates containers

Typical Workflows



Dockerizing an application



Pushing an image to a registry

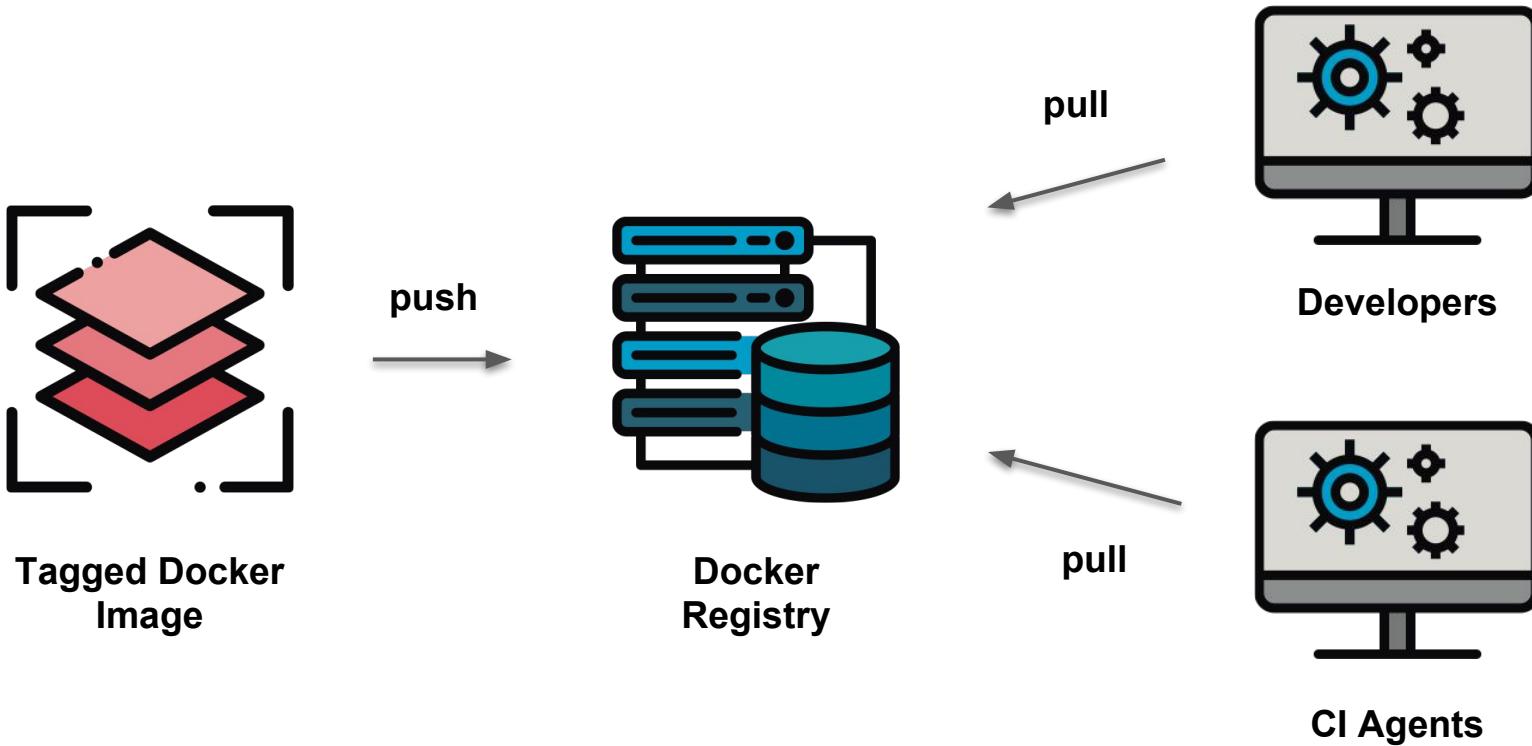
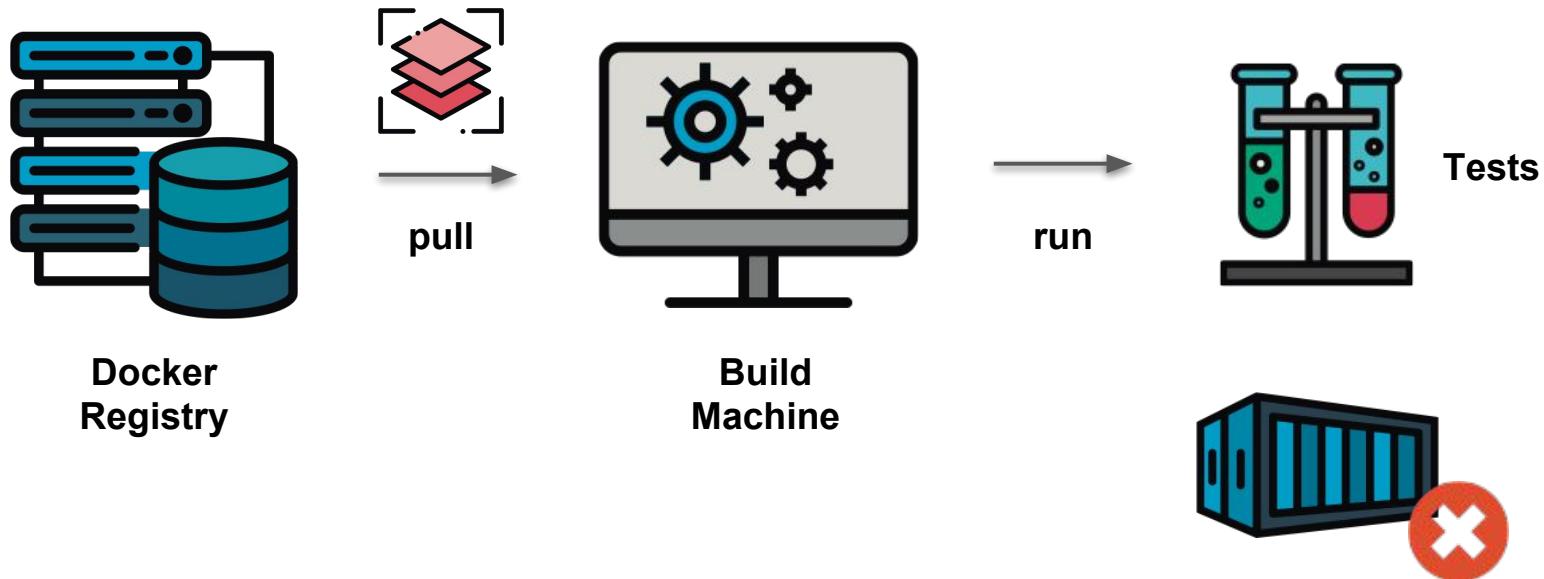
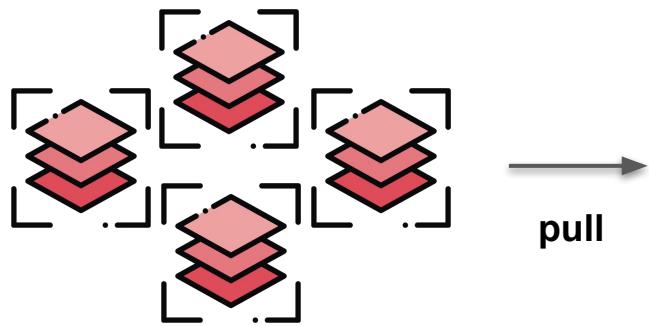


Image as fixture for testing

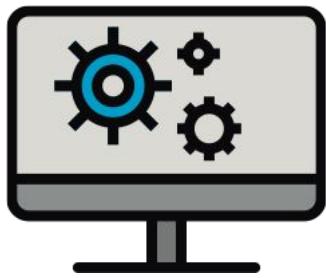


Running application stacks



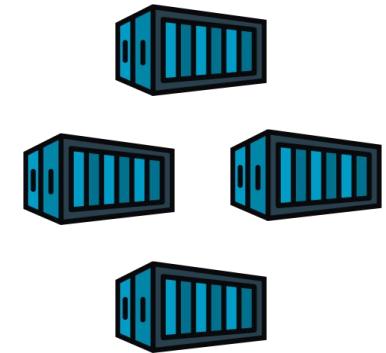
Multiple Docker Images

pull

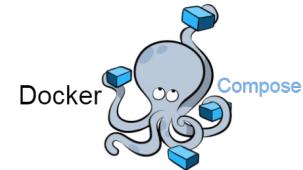


Build Machine

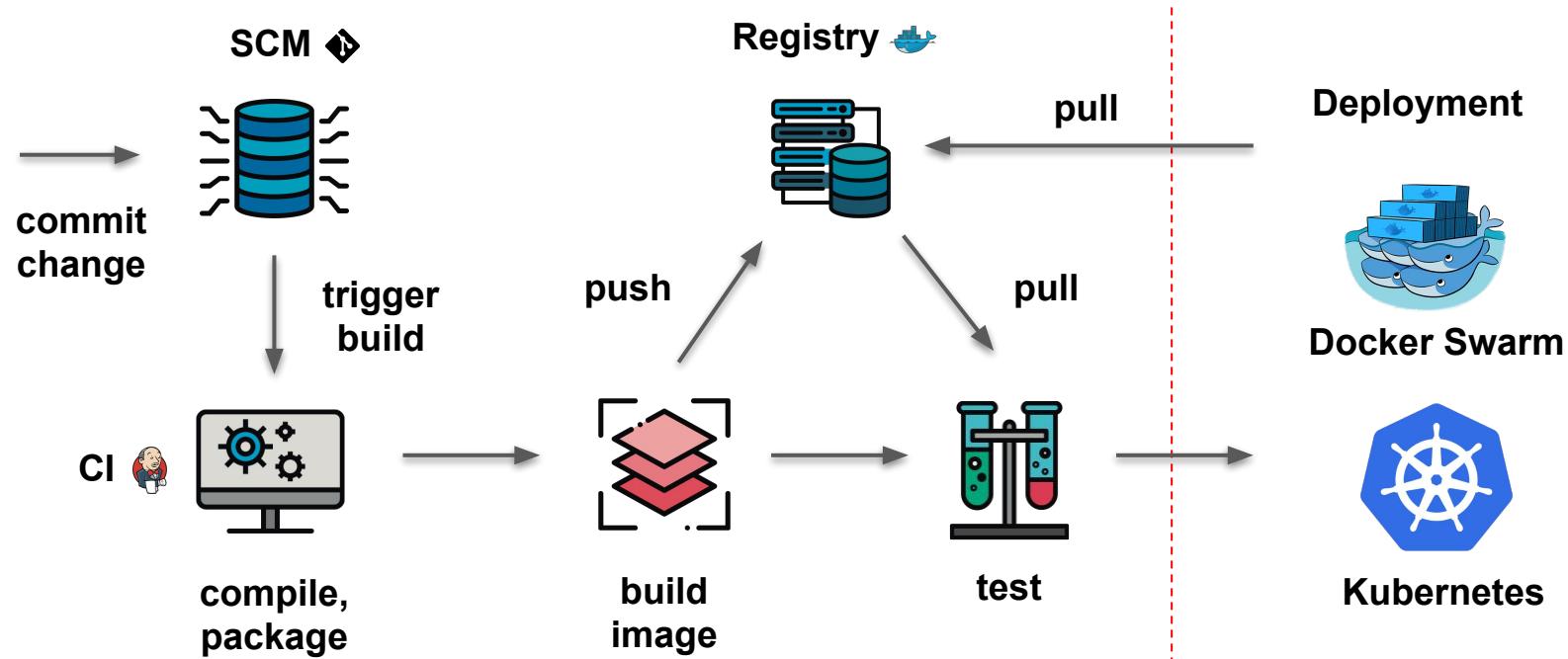
run



Multi-container Application



Docker as part of a build pipeline

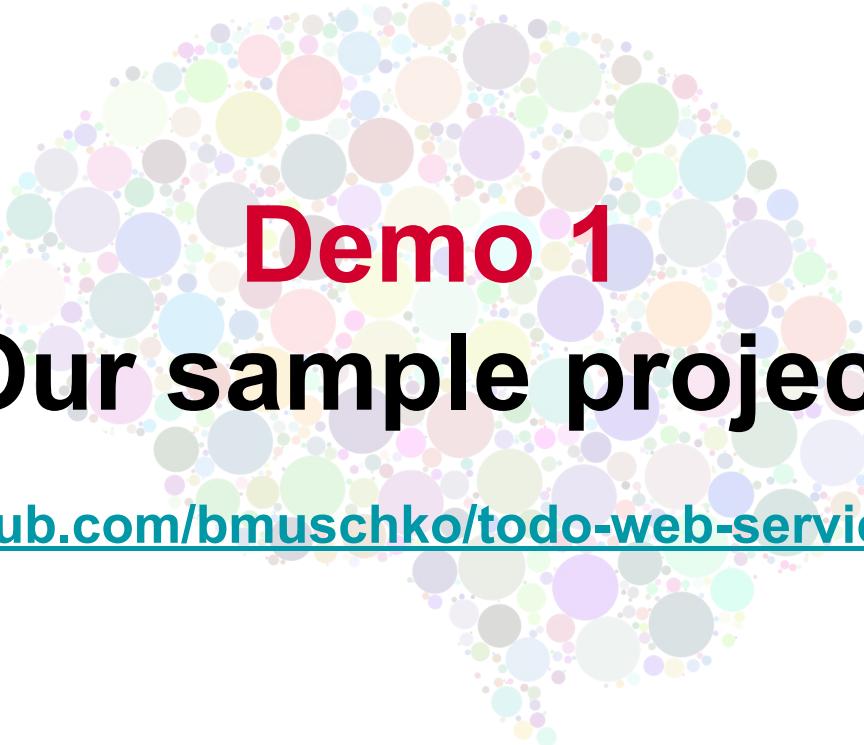


~~Ops~~



Discussion

**Are there other
workflows you
have to implement?**



Demo 1

Our sample project

<https://github.com/bmuschko/todo-web-service-exercise>

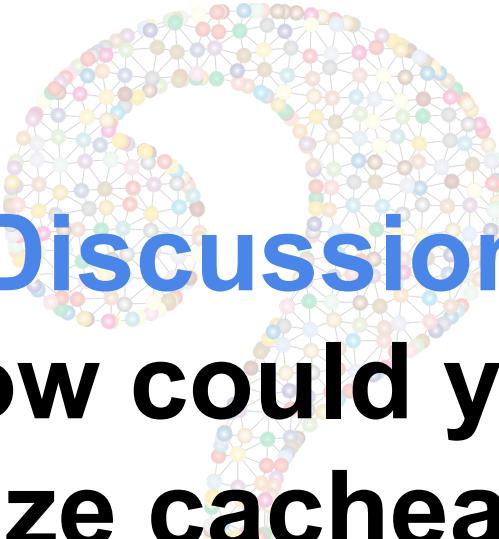
Containerization

Writing a Dockerfile for a Java application

- Pick a base image that's as small as possible
- Copy application files as directories or archive?
- Providing runtime configuration
- Ensuring application readiness with a health check

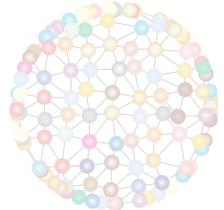
Dockerfile for a Spring Boot application

```
FROM openjdk:jre-alpine
COPY todo-webservice-1.0.jar \
     /app/todo-webservice-1.0.jar
ENTRYPOINT ["java"]
CMD ["-jar", "/app/todo-webservice-1.0.jar"]
HEALTHCHECK CMD wget --quiet --tries=1 --spider \
             http://localhost:8080/actuator/health || exit 1
EXPOSE 8080
```



Discussion

How could you optimize cacheability?



Dockerfile with layers for application files

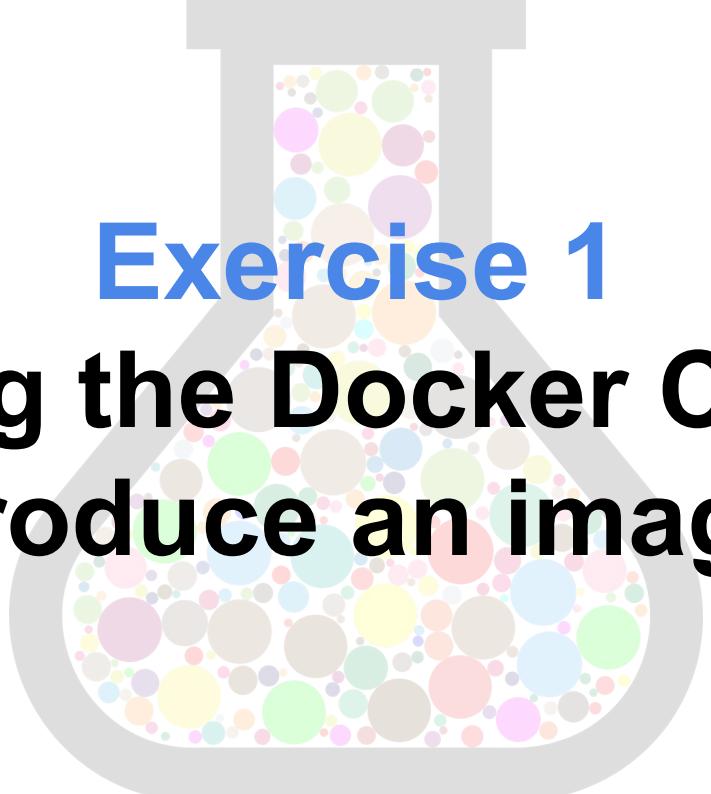
```
FROM openjdk:jre-alpine
WORKDIR /app
COPY libs libs/
COPY resources resources/
COPY classes classes/
ENTRYPOINT ["java", "-cp",
            "/app/resources:/app/classes:/app/libs/*",
            "com.bmuschko.MyApplication"]
HEALTHCHECK CMD wget --quiet --tries=1 --spider
              http://localhost:8080/actuator/health || exit 1
EXPOSE 8080
```

Building an image

```
# Build image from Dockerfile
$ docker build -t todo-web-service:1.0.0 .
e14f431c33a2

# List the images
$ docker images

REPOSITORY          TAG      IMAGE ID      CREATED     SIZE
todo-web-service   1.0      e14f431c33a2  45 hours ago  99MB
openjdk             jre-alpine  ccfb0c83b2fe  6 months ago  83MB
```



Exercise 1

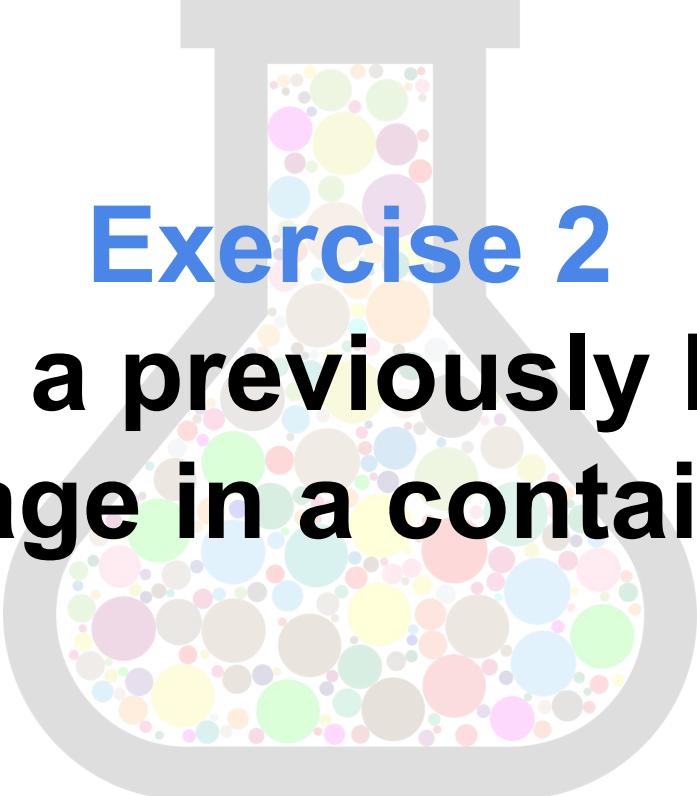
Using the Docker CLI to produce an image

Running an image

```
# Run built image in container
$ docker run -d -p 8080:8080 todo-web-service:1.0.0
3760ac0bc8c68283473e5dff123714...

# List the running container
$ docker container ls

CONTAINER ID IMAGE COMMAND CREATED
3760ac0bc8c6 todo-web-service "java -cp /app/resou..." 32<
seconds ago
```



Exercise 2

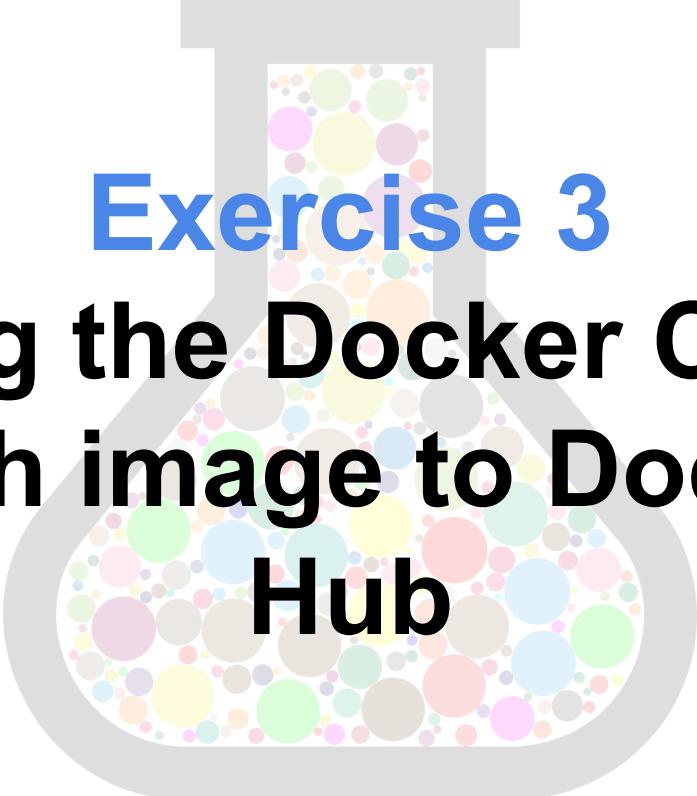
Run a previously built image in a container

Pushing an image to Docker Hub

```
# Log into Docker Hub
$ docker login --username=bmuschko

# Tag the image
$ docker tag bb38976d03cf<+
    bmuschko/todo-web-service:1.0.0

# Push image to Docker registry
$ docker push bmuschko/todo-web-service:1.0.0
```



Exercise 3

Using the Docker CLI to push image to Docker Hub

Docker's CLI is great but do I
need to operate it by hand?



Automate containerization with Jib

- Build images without the need for Docker Engine
- Dockerfile is optional
- Separates application files for cacheability
- Runs as Java library or Maven/Gradle plugins



Using the Jib Maven plugin

pom.xml

```
<project>
  ...
  <build>
    <plugins>
      ...
      <plugin>
        <groupId>com.google.cloud.tools</groupId>
        <artifactId>jib-maven-plugin</artifactId>
        <version>1.0.2</version>
        <configuration>
          <to>
            <image>myimage</image>
            <to>
          </configuration>
        </plugin>
      ...
    </plugins>
  </build>
  ...
</project>
```

Building the image

```
$ mvn compile jib:build
```

Using the Jib Gradle plugin

build.gradle

```
plugins {
    id 'java'
    id 'com.google.cloud.tools.jib' version '1.0.2'
}

jib.to.image = 'bmuschko/java-app-jib:1.0'
```

Building the image

```
$ gradle jib
```

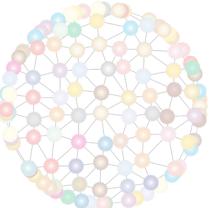


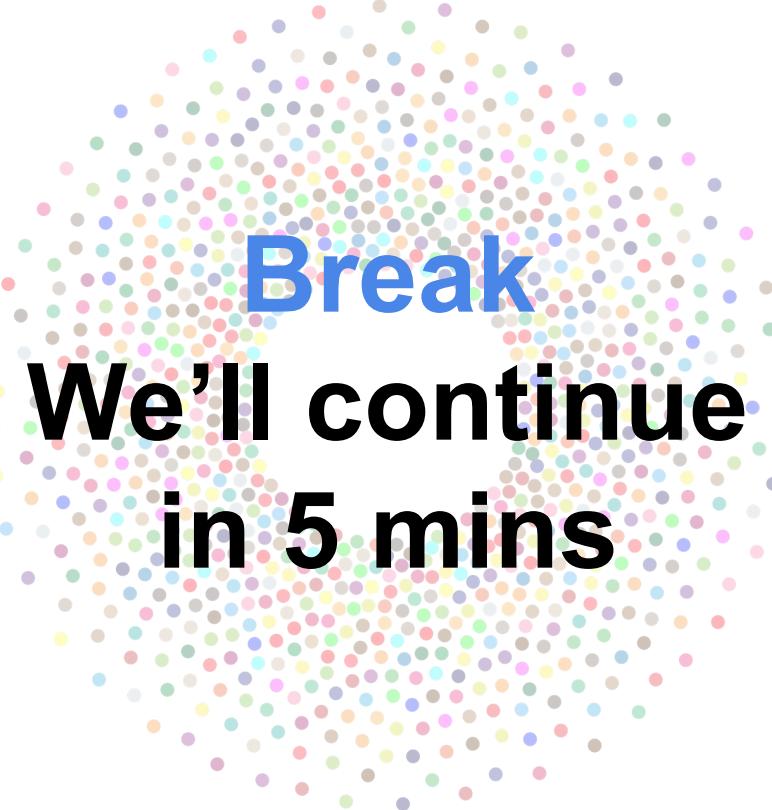
Exercise 4

Using Jib to implement the containerization workflow



**Please ask
questions!**

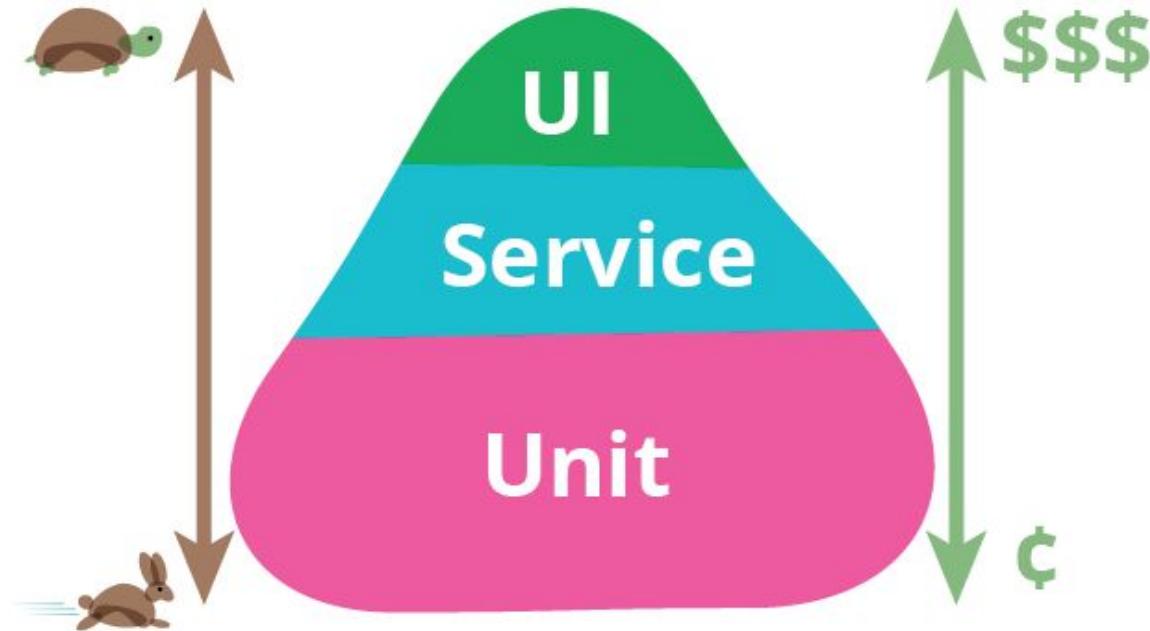




Break
We'll continue
in 5 mins

Testing  3

The testing pyramid

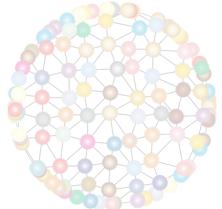


Source: <https://martinfowler.com/bliki/TestPyramid.html>



Discussion

Who writes integration or functional tests?



2 unit tests, 0 integration tests



Reproducible environment

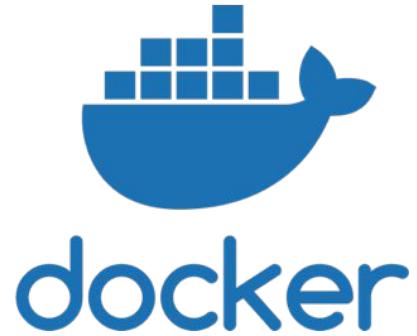


Slow startup times



Isolated & Cross-platform





The obvious choice



Java library for managing
Docker containers in JUnit tests

<https://www.testcontainers.org/>

Docker Engine Communication



Docker environment discovery



Automatic container cleanup



TestContainers dependencies in Maven

pom.xml

```
<dependency>
    <groupId>org.testcontainers</groupId>
    <artifactId>testcontainers</artifactId>
    <version>1.10.7</version>
    <scope>test</scope>
</dependency>
```



TestContainers libraries [available on Maven Central](#)

TestContainers dependencies in Gradle

build.gradle

```
repositories {  
    jcenter()  
}  
  
dependencies {  
    testImplementation 'org.testcontainers:junit-jupiter:1.10.7'  
    testImplementation 'org.testcontainers:postgresql:1.10.7'  
    testRuntime 'org.postgresql:postgresql'  
}
```



[Bintray JCenter](#) as proxy for Maven Central

Creating a database container

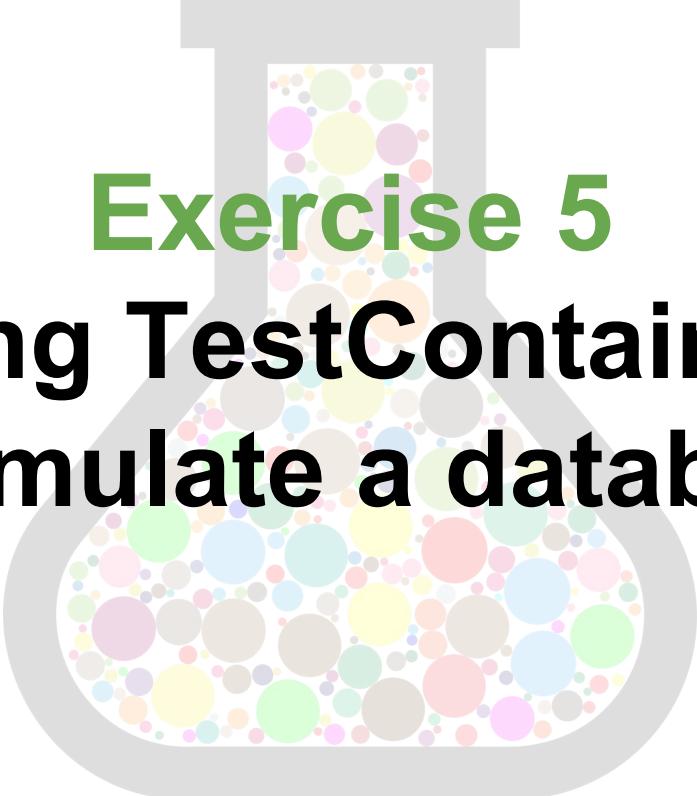
```
import org.testcontainers.containers.PostgreSQLContainer;
import org.testcontainers.junit.jupiter.Container;
import org.testcontainers.junit.jupiter.Testcontainers;

@Testcontainers
public class DatabaseIntegrationTest {

    @Container
    public static PostgreSQLContainer container =
        new PostgreSQLContainer("postgres:9.6.10-alpine")
            .withUsername("username")
            .withPassword("pwd")
            .withDatabaseName("todo");
}
```

Accessing runtime container information

```
static class Initializer implements↓
    ApplicationContextInitializer<ConfigurableApplicationContext> {
    @Override
    public void initialize(ConfigurableApplicationContext↓
        configurableApplicationContext) {
        TestPropertyValues.of(
            "spring.datasource.url=" + container.getJdbcUrl(),
            "spring.datasource.username=" + container.getUsername(),
            "spring.datasource.password=" + container.getPassword(),
            "spring.datasource.driver-class-name=org.postgresql.Driver",
            "spring.jpa.generate-ddl=true"
        ).applyTo(configurableApplicationContext.getEnvironment());
    }
}
```



Exercise 5

Using TestContainers to emulate a database

Creating multiple containers

```
import org.testcontainers.containers.DockerComposeContainer;
import org.testcontainers.junit.jupiterContainer;
import org.testcontainers.junit.jupiterTestcontainers;

import java.io.File;

@Testcontainers
public class DockerComposeIntegrationTest {

    private final static File PROJECT_DIR = new File(System.getProperty("project.dir"));
    private final static String POSTGRES_SERVICE_NAME = "database_1";
    private final static int POSTGRES_SERVICE_PORT = 5432;

    @Container
    public static DockerComposeContainer environment = createComposeContainer();

    private static DockerComposeContainer createComposeContainer() {
        return new DockerComposeContainer(new File(PROJECT_DIR,
            "src/test/resources/compose-test.yml"))
            .withExposedService(POSTGRES_SERVICE_NAME, POSTGRES_SERVICE_PORT);
    }
}
```

Sample Docker Compose file

compose-test.yml

```
database:  
  image: "postgres:9.6.10-alpine"  
  environment:  
    - POSTGRES_USER=postgres  
    - POSTGRES_PASSWORD=postgres  
    - POSTGRES_DB=todo  
elasticsearch:  
  image: "elasticsearch"
```

Doesn't follow the Compose spec 100%

Accessing runtime container information

```
private static String getPostgresServiceUrl() {  
    String postgresHost =  
        environment.getServiceHost(POSTGRES_SERVICE_NAME,  
                                    POSTGRES_SERVICE_PORT);  
    Integer postgresPort =  
        environment.getServicePort(POSTGRES_SERVICE_NAME,  
                                    POSTGRES_SERVICE_PORT);  
    StringBuilder postgresServiceUrl = new StringBuilder();  
    postgresServiceUrl.append("jdbc:postgresql://");  
    postgresServiceUrl.append(postgresHost);  
    postgresServiceUrl.append(":");  
    postgresServiceUrl.append(postgresPort);  
    postgresServiceUrl.append("/todo");  
    return postgresServiceUrl.toString();  
}
```

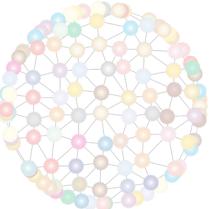


Exercise 6

Using Docker Compose with TestContainers



**Please ask
questions!**



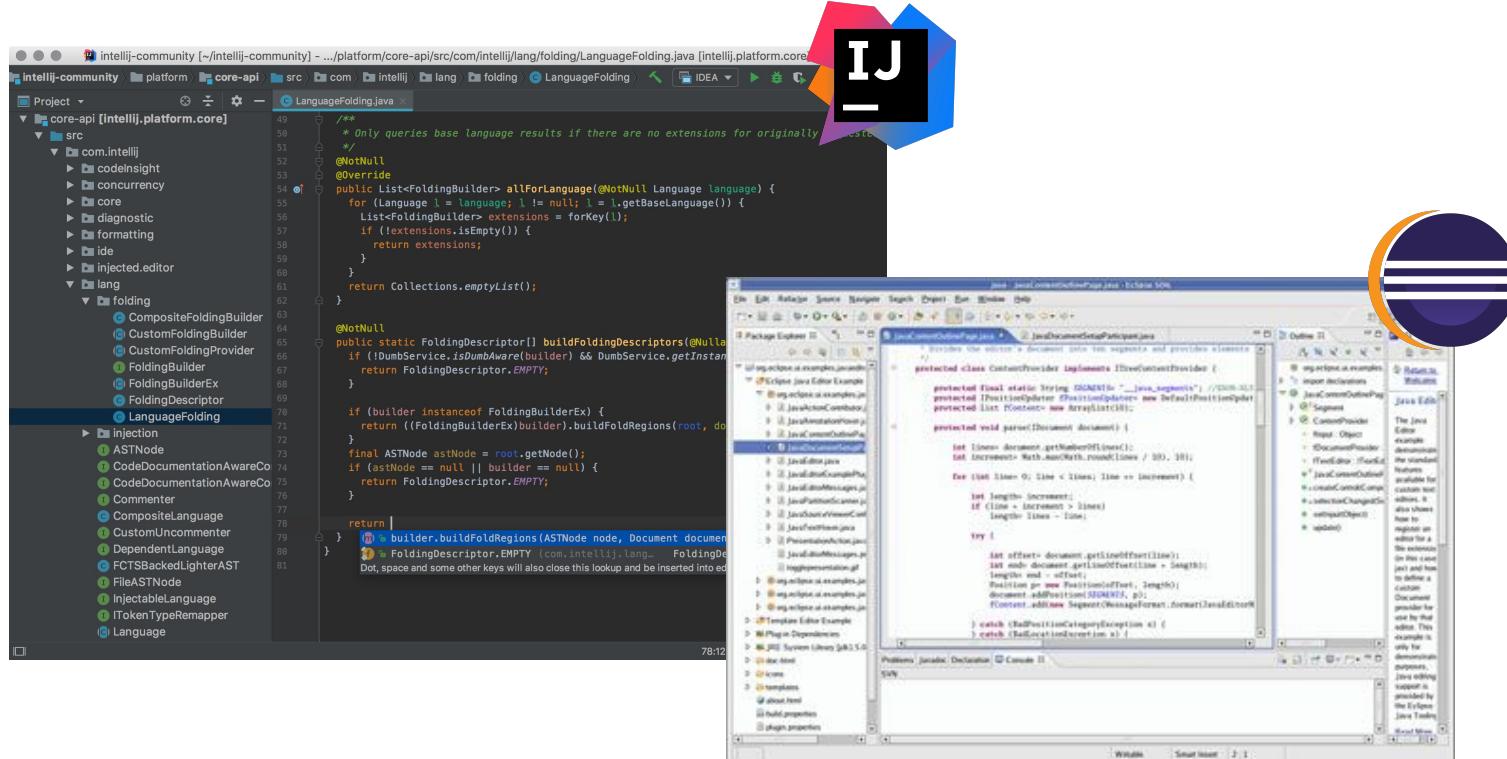


Break
We'll continue
in 5 mins

Tooling integration

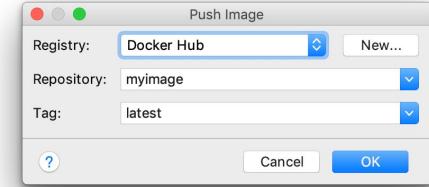
4

IDE support for Docker

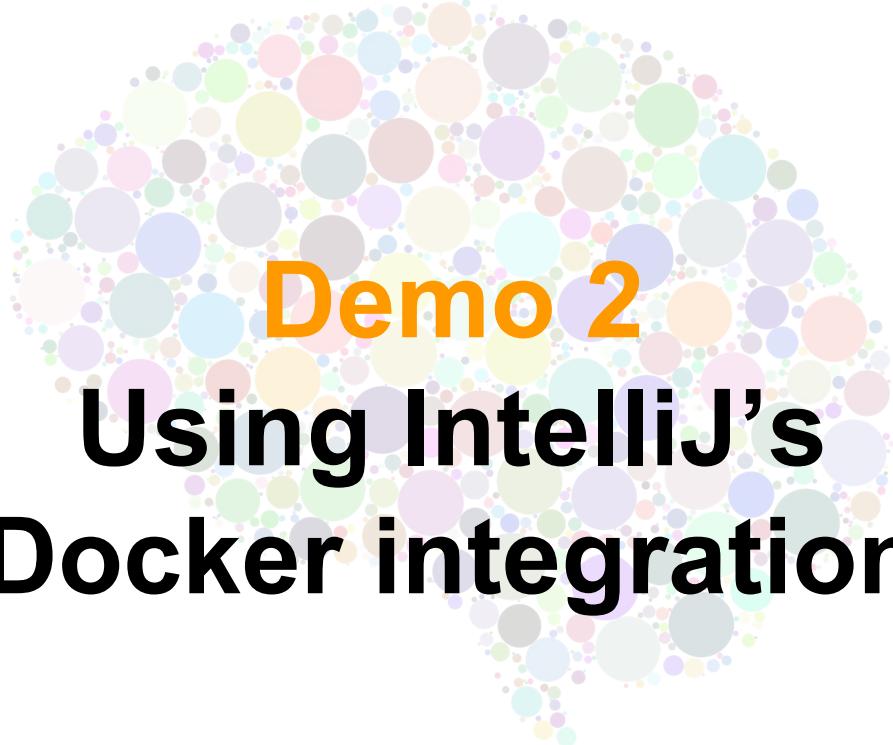


Docker in IntelliJ

- Browse images and containers
- Create images from Dockerfile
- Create a container from an image
- Push an image to a registry



<https://plugins.jetbrains.com/plugin/7724-docker-integration>



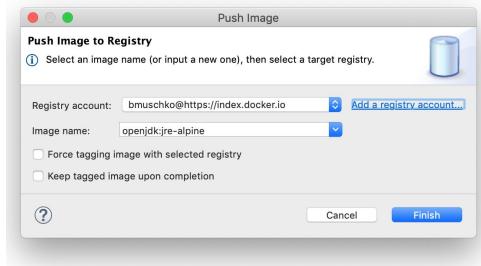
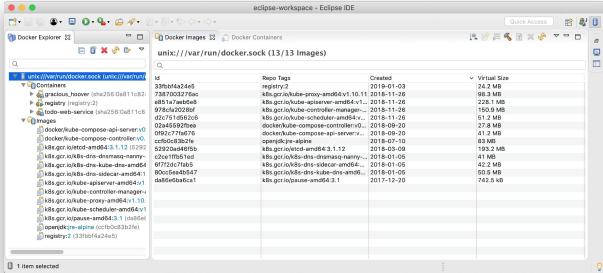
Demo 2

Using IntelliJ's

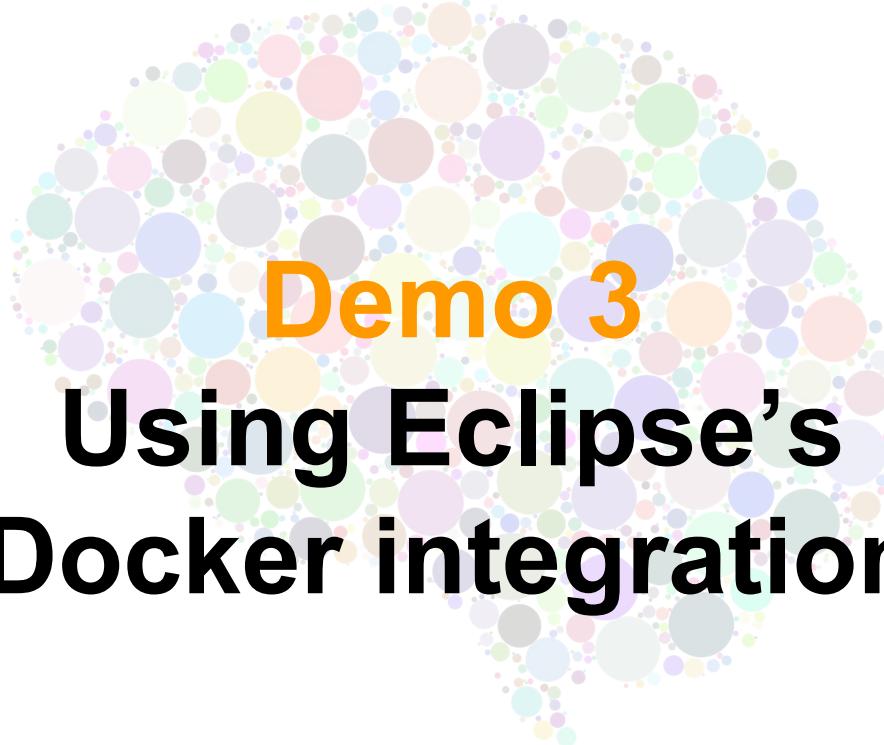
Docker integration

Docker in Eclipse

- Base capabilities as IntelliJ
- Loading and saving an image
- Compatible with Oxygen & Neon
- Avoid drag & drop installation



<https://marketplace.eclipse.org/content/eclipse-docker-tooling>



Demo 3

Using Eclipse's

Docker integration



Exercise 7

Running a container from IntelliJ IDEA

Fine-grained build tool support for Docker



```
1. bmuschko@ascent: ~/dev/projects/todo-web-service-exercise (zsh)
~/dev/projects/todo-web-service-exercise [master] > ./mvnw clean install
[INFO] Scanning for projects...
[INFO]
[INFO] --- com.bmuschko:todo-web-service-exercise >---
[INFO] Building todo-web-service-exercise 1.0.0
[INFO]   [ jar ]
[INFO]
[INFO] --- maven-clean-plugin:3.1.0:clean (default-clean) @ todo-web-service-exercise ---
[INFO] Deleting /Users/bmuschko/dev/projects/todo-web-service-exercise/target
[INFO]
[INFO] --- maven-resources-plugin:3.1.0:resources (default-resources) @ todo-web-service-exercise ---
[INFO] Using 'UTF-8' encoding to copy filtered resources.
[INFO] Copying 1 resource
[INFO] Copying 0 resource
[INFO]
[INFO] --- maven-compiler-plugin:3.8.0:compile (default-compile) @ todo-web-service-exercise ---
[INFO] Changes detected - recompiling the module!
[INFO] Compiling 5 source files to /Users/bmuschko/dev/projects/todo-web-service-exercise/
[INFO] --- maven-resources-plugin:3.1.0:testResources (default-testResources) @ todo-web-service-exercise ---
[INFO] Using 'UTF-8' encoding to copy filtered resources.
[INFO] skip non existing resourceDirectory /Users/bmuschko/dev/projects/todo-web-service-exercise/
[INFO] --- maven-compiler-plugin:3.8.0:testCompile (default-testCompile) @ todo-web-service-exercise ---
[INFO] No sources to compile
[INFO]
[INFO] --- maven-surefire-plugin:2.22.1:test (default-test) @ todo-web-service-exercise --> Task :jar SKIPPED
[INFO] No tests to run.
[INFO]
[INFO] --- maven-jar-plugin:3.1.1:jar (default-jar) @ todo-web-service-exercise --> Task :clean
[INFO] Building jar: /Users/bmuschko/dev/projects/todo-web-service-exercise/target/todo-web-service-exercise-1.0.0.jar
[INFO]
[INFO] --- maven-install-plugin:2.5.2:install (default-install) @ todo-web-service-exercise --> Task :test NO-SOURCE
[INFO] Downloading from central: https://repo.maven.apache.org/maven2/commons-codec/commons-codec/1.15.0/maven-metadata.xml
[INFO] Downloaded from central: https://repo.maven.apache.org/maven2/commons-codec/commons-codec/1.15.0/maven-metadata.xml (5 kB/s)
[INFO] Downloading from central: https://repo.maven.apache.org/maven2/org/apache/maven/shared/maven-shared-components/0.4.0/maven-shared-components-0.4.0.pom
[INFO]
```

```
1. bmuschko@ascent: ~/dev/projects/todo-web-service-exercise (zsh)
~/dev/projects/todo-web-service-exercise [master] > ./gradlew clean build --console=verbose
[INFO] Task :clean
[INFO] Task :compileJava
[INFO] Task :processResources
[INFO] Task :classes
[INFO] Task :bootJar
[INFO] --- maven-compiler-plugin:3.8.0:testCompile (default-testCompile) @ todo-web-service-exercise ---
[INFO] No sources to compile
[INFO]
[INFO] --- maven-surefire-plugin:2.22.1:test (default-test) @ todo-web-service-exercise --> Task :jar UP-TO-DATE
[INFO] No tests to run.
[INFO]
[INFO] --- maven-jar-plugin:3.1.1:jar (default-jar) @ todo-web-service-exercise --> Task :clean
[INFO] Building jar: /Users/bmuschko/dev/projects/todo-web-service-exercise/target/todo-web-service-exercise-1.0.0.jar
[INFO]
[INFO] --- maven-install-plugin:2.5.2:install (default-install) @ todo-web-service-exercise --> Task :check UP-TO-DATE
[INFO] Downloading from central: https://repo.maven.apache.org/maven2/commons-codec/commons-codec/1.15.0/maven-metadata.xml
[INFO] Downloaded from central: https://repo.maven.apache.org/maven2/commons-codec/commons-codec/1.15.0/maven-metadata.xml (5 kB/s)
[INFO] Downloading from central: https://repo.maven.apache.org/maven2/org/apache/maven/shared/maven-shared-components/0.4.0/maven-shared-components-0.4.0.pom
[INFO] BUILD SUCCESSFUL in 1s
4 actionable tasks: 4 executed
~/dev/projects/todo-web-service-exercise [master] >
```



Driving Docker from Maven

- Create Dockerfile, build & push image
- Starting/stopping containers for testing
- Support for Docker Compose

<https://github.com/fabric8io/docker-maven-plugin>

Configuring the plugin

pom.xml

```
<plugin>
  <groupId>io.fabric8</groupId>
  <artifactId>docker-maven-plugin</artifactId>
  <version>0.28.0</version>
  <configuration>
    ...
    <images>
      <image>
        ...
      </image>
      ...
    </images>
  </configuration>
</plugin>
```

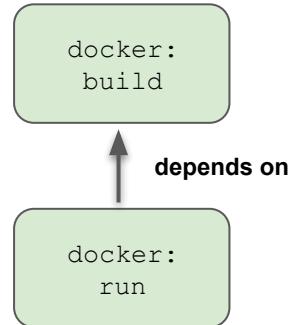
Building an image, running a container

pom.xml

```
<plugin>
  ...
  <configuration>
    <images>
      <image>
        <name>hello/sub/project/java:${project.version}</name>
        <alias>hello-world</alias>
        <build>
          <from>openjdk:latest</from>
          <assembly>
            <descriptorRef>artifact</descriptorRef>
          </assembly>
          <cmd>java -jar maven/${project.name}-${project.version}.jar</cmd>
        </build>
        <run>
          <wait>
            <log>Hello World!</log>
          </wait>
        </run>
      </image>
    </images>
  </configuration>
</plugin>
```

Goal execution from the command line

```
$ mvn package docker:build docker:run
...
[INFO]
[INFO] --- maven-jar-plugin:3.0.2:jar (default-jar) @ dmp-sample-helloworld ---
[INFO]
[INFO] --- docker-maven-plugin:0.28.0:build (default-cli) @ dmp-sample-helloworld ---
[INFO] Copying files to
/Users/bmuschko/dev/projects/docker-maven-plugin/samples/helloworld/target/docker/hello/sub/p
roject/java/0.28-SNAPSHOT/build/maven
[INFO] Building tar:
/Users/bmuschko/dev/projects/docker-maven-plugin/samples/helloworld/target/docker/hello/sub/p
roject/java/0.28-SNAPSHOT/tmp/docker-build.tar
[INFO] DOCKER> [hello/sub/project/java:0.28-SNAPSHOT] "hello-world": Created docker-build.tar
in 91 milliseconds
[INFO] DOCKER> [hello/sub/project/java:0.28-SNAPSHOT] "hello-world": Built image sha256:611f9
[INFO]
[INFO] --- docker-maven-plugin:0.28.0:run (default-cli) @ dmp-sample-helloworld ---
[INFO] DOCKER> [hello/sub/project/java:0.28-SNAPSHOT] "hello-world": Start container
78f25f507d9a
[INFO] DOCKER> Pattern 'Hello World!' matched for container 78f25f507d9a
hello-world> Hello World!
[INFO] DOCKER> [hello/sub/project/java:0.28-SNAPSHOT] "hello-world": Waited on log out 'Hello
World!' 687 ms
```



Using Docker Compose

pom.xml

```
<image>
    <alias>webapp</alias>
    <name>fabric8/compose-demo:latest</name>

    <external>
        <type>compose</type>
        <basedir>src/main/docker</basedir>
        <composeFile>docker-compose.yml</composeFile>
    </external>

    <build>
        <assembly>....</assembly>
    </build>
    <run>...</run>
    <watch>...</watch>
</image>
```

Driving Docker from Gradle

- Models most Docker operations as custom tasks
- Communicates via Docker Engine RESTful API
- Convention plugins for Java and Spring Boot apps
- Compatible with Groovy and Kotlin DSL

<https://github.com/bmuschko/gradle-docker-plugin>

Building a Docker image with custom tasks

build.gradle

```
plugins {
    id 'com.bmuschko.docker-remote-api' version '4.6.2'
}

import com.bmuschko.gradle.docker.tasks.image.Dockerfile
import com.bmuschko.gradle.docker.tasks.image.DockerBuildImage

task dockerfile(type: Dockerfile) {
    from 'ubuntu:12.04'
    label(['maintainer': 'John Doe'])
}

task buildImage(type: DockerBuildImage) {
    dependsOn dockerfile
    tags.add('jdoe/myimage:latest')
}
```

Task execution from the command line

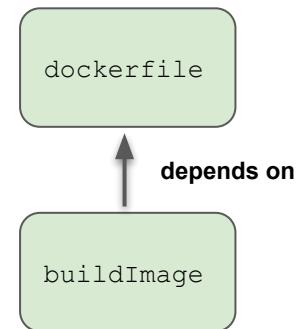
```
$ gradle buildImage --console=verbose
> Task :dockerfile
Step 1/2 : FROM ubuntu:12.04

---> 5b117edd0b76
Step 2/2 : LABEL maintainer="John Doe"

---> Using cache
---> b3edd0b8fac5
Successfully built b3edd0b8fac5
Successfully tagged jdoe/myimage:latest

> Task :buildImage
Building image using context
'/Users/bmuschko/dev/projects/gradle/build/docker'.
Using tags 'jdoe/myimage:latest' for image.
Created image with ID 'b3edd0b8fac5'.

BUILD SUCCESSFUL in 8s
2 actionable tasks: 1 executed, 1 up-to-date
```



Convention support for Spring Boot apps

build.gradle

```
plugins {
    id 'war'
    id 'org.springframework.boot' version '2.0.3.RELEASE'
    id 'io.spring.dependency-management' version '1.0.5.RELEASE'
    id 'com.bmuschko.docker-spring-boot-application' version '4.6.2'
}

repositories {
    jcenter()
}

dependencies {
    implementation 'org.springframework.boot:spring-boot-starter-web'
    providedRuntime 'org.springframework.boot:spring-boot-starter-tomcat'
    providedRuntime 'org.apache.tomcat.embed:tomcat-embed-jasper'
}
```

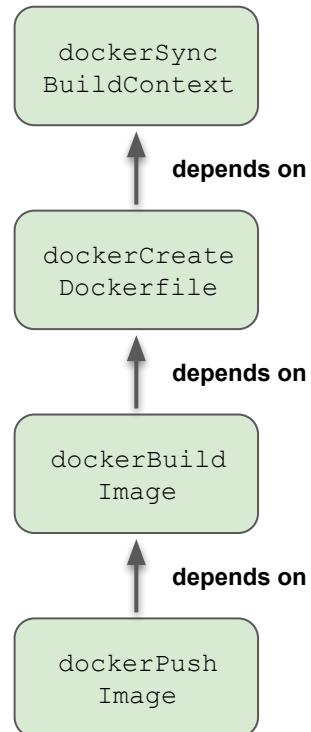
Task execution from the command line

```
$ gradle dockerPushImage --console=verbose
> Task :compileJava
> Task :processResources NO-SOURCE
> Task :classes
> Task :dockerSyncBuildContext
> Task :dockerCreateDockerfile
...
Successfully built d677dcfab7c4
Successfully tagged bmuschko/springbootapp:latest

> Task :dockerBuildImage
Created image with ID 'd677dcfab7c4'.

> Task :dockerPushImage
Pushing image with name 'bmuschko/springbootapp'.

BUILD SUCCESSFUL in 26s
6 actionable tasks: 6 executed
```



Using Docker Compose from Gradle

- There's no one-stop solution
- Offers all Docker Compose operations
- Helpful for local development and integ. testing

<https://github.com/avast/gradle-docker-compose-plugin>

Using the Avast Docker Compose plugin

build.gradle

```
plugins {  
    id 'com.avast.gradle.docker-compose' version '0.9.1'  
}  
  
dockerCompose {  
    useComposeFiles = ['docker-compose.yml']  
}
```

```
plugins {  
    id 'java'  
}  
  
dockerCompose {  
   isRequiredBy(project.tasks.test)  
    exposeAsSystemProperties(project.tasks.test)  
}
```

**Hooking
into test
execution**



Task execution from the command line

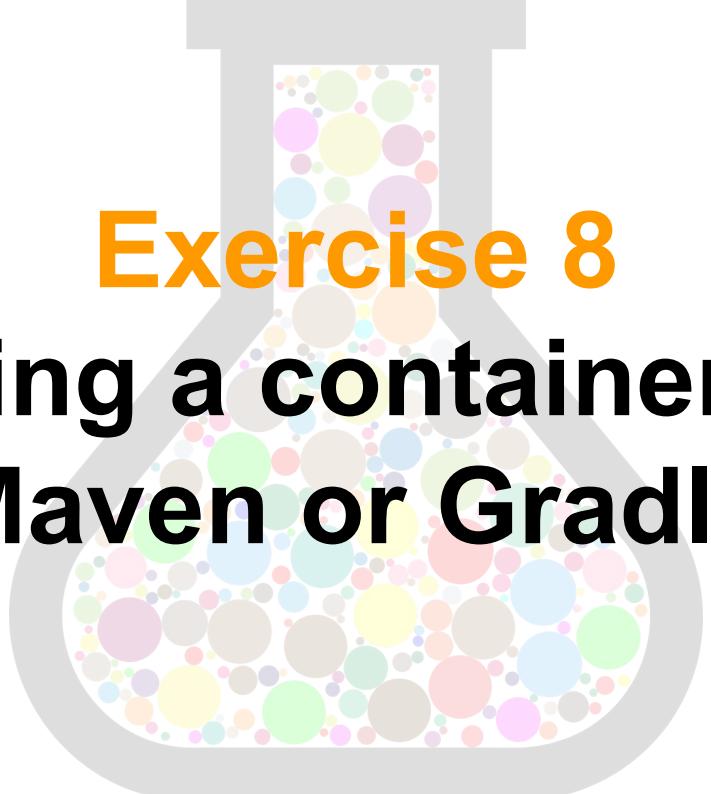
```
$ ./gradlew composeUp
> Task :composeUp
redis uses an image, skipping
Building web
Creating network
"dockercomposeintegrationtesting_counter-net" with the
default driver
Creating volume
"dockercomposeintegrationtesting_counter-vol" with default
driver
Creating dockercomposeintegrationtesting_redis_1 ... done
Creating dockercomposeintegrationtesting_web_1 ... done
Will use localhost as host of redis
Will use localhost as host of web
Waiting for redis_1 to become healthy (it's starting)
redis_1 health state reported as 'healthy' - continuing...
Waiting for web_1 to become healthy (it's starting)
web_1 health state reported as 'healthy' - continuing...
Probing TCP socket on localhost:5000 of service 'web_1'
TCP socket on localhost:5000 of service 'web_1' is ready

BUILD SUCCESSFUL in 1m 48s
1 actionable task: 1 executed
```

composeUp

...

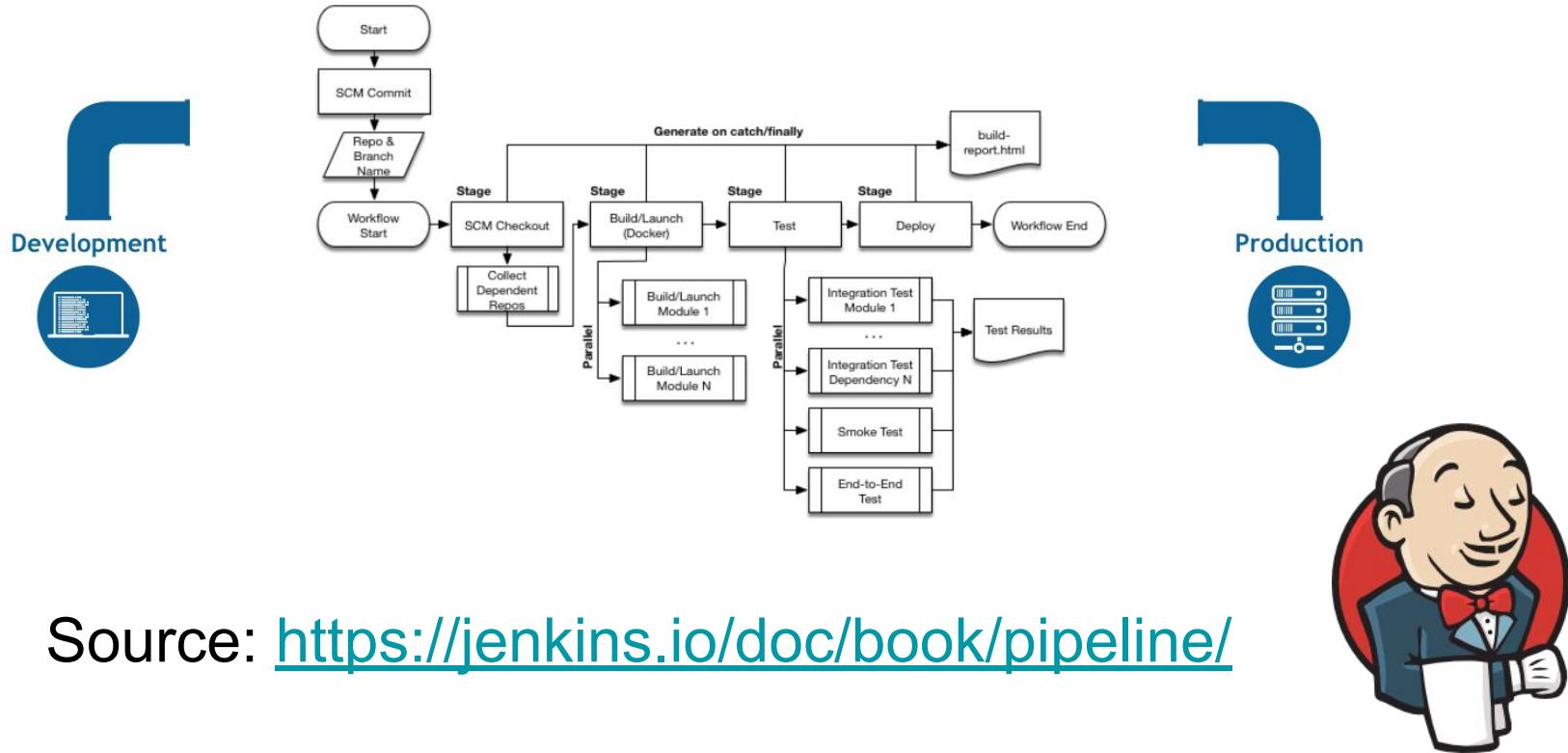
compose
Down



Exercise 8

Running a container from Maven or Gradle

CI/CD pipelines involving Docker



Issues with manual job creation



Jenkins 2 pipelines

- Configuration as code
- Groovy as DSL in Jenkinsfile
- Declarative pipeline definition
- [Syntax documentation](#)



Pipeline visualization

todo-web-service - Stage View

Average stage times:
(Average full run time: ~2min 52s)

	Declarative: Checkout SCM	Compile & Unit Tests	Integration Tests	Assembly	Build Image	Functional Tests	Push Image	Deploy to Production	Declarative: Post Actions
#52 Oct 22 09:17 No Changes	779ms	4s	9s	4s	7s	33s	29s	1min 15s	79ms
#51 Screenshot 08:59	512ms	9s	8s	3s	7s	36s	50s	43s (paused for 7s)	
#50 Oct 22 08:57 1 commit	610ms	8s	8s	4s	9s	39s	36s	161ms (paused for 1min 16s) aborted	
#29 Oct 19 15:40 5 commits	858ms	9s	8s	4s	16s	3s failed	53ms failed	36ms failed	118ms
#28 Oct 04 17:00 No Changes	763ms	4s	10s	4s	6s				
	1s	3s	11s	4s	6s				

✓ todo-web-service < 32 Pipeline Changes Tests Artifacts ⚡⚙️🔗Logout X

Branch: — 2m 49s No changes
Commit: — 3 months ago Started by user Benjamin Muschko

Start → Compile & Unit Tests → Integration Tests → Assembly → Build Image → Functional Tests → Push Image

Deploy to Production - 51

✓ > Deploy to Production? — Wait for interactive input 7s

✓ > Shell Script 43s

Standard

Blue Ocean

Required Jenkins plugins

- Suite of pipeline plugin (standard)
- Blue Ocean plugin (optional)

 **Manage Plugins**
Add, remove, disable or enable plugins that can extend the functionality of Jenkins.
⚠ There are updates available

 **Blue Ocean**
BlueOcean Aggregator

 **Pipeline**
A suite of plugins that lets you orchestrate automation, simple or complex. See [Pipeline as Code with Jenkins](#) for more details.



Demo 4

Creating a pipeline job

Syntax element: Pipeline

```
pipelines {  
    . . .  
}
```

Models CI pipeline including stages for building, testing, releasing application

Syntax element: Agent

```
pipelines {  
    agent any  
}
```

```
pipelines {  
    agent {  
        docker {  
            image 'maven3-alpine'  
            label  
            'my-defined-label'  
            arg '-v /tmp:tmp'  
        }  
    }  
}
```

“where does the pipeline execute”

Syntax element: Stage

```
pipelines {  
    agent any {  
        stages {  
            stage('Build') {  
                steps {  
                    ...  
                }  
            }  
        }  
    }  
}
```

Subset of tasks, visualized in UI

Syntax element: Steps

```
pipelines {  
    agent any {  
        stages {  
            stage('Build') {  
                steps {  
                    ...  
                }  
            }  
        }  
    }  
}
```

Single task, “what to execute”

There's more...

- Using pre-defined [tools](#)
- Using [environment variables and credentials](#)
- [Post-build](#) notifications
- Requesting [user input](#)
- [Conditional](#) execution of stages

Example step for compiling code

```
pipelines {  
    agent any {  
        stages {  
            stage('Compile') {  
                steps {  
                    sh './mvnw compile'  
                }  
            }  
            stage('...') {  
                ...  
            }  
        }  
    }  
}
```

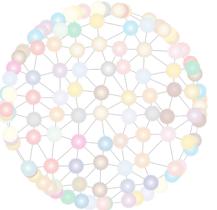
**Shell
Command**

Exercise 9

Using Docker in a Jenkins build pipeline



**Please ask
questions!**





Conclusion
Let's summarize
what we've learned

