CS544

LESSON 13
MONITORING

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
March 28 **Lesson 1** Enterprise Architecture introduction and Spring Boot	March 29 **Lesson 2** Dependency injection AOP	March 30 **Lesson 3** JDBC JPA	March 31 **Lesson 4** JPA mapping 1	April 1 **Lesson 5** JPA mapping 2	April 2 **Lesson 6** JPA queries	April 3
April 4 **Lesson 7** Transactions	April 5 **Lesson 8** MongoDB	April 6 **Midterm Review**	April 7 **Midterm exam**	April 8 **Lesson 9** REST webservices	April 9 **Lesson 10** SOAP webservices	April 10
April 11 **Lesson 11** Messaging	April 12 **Lesson 12** Scheduling Events Configuration	April 13 **Lesson 13** Monitoring	April 14 **Lesson 14** Testing your application	April 15 **Final review**	April 16 **Final exam**	April 17
April 18 **Project**	April 19 **Project**	April 20 **Project**	April 21 **Presentations**			

SPRING BOOT LOGGING

Zero configuration logging

```
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-logging</artifactId>
</dependency>
```

- When you add this dependency, Spring boot automatically uses Log4J for logging.

Using a Logger

```
@Component
public class CustomerService {
   Logger logger = LoggerFactory.getLogger(CustomerService.class);

   public void addCustomer(){
      logger.trace("A TRACE Message");
   }

   public void updateCustomer(){
      logger.debug("A DEBUG Message");
   }

   public void removeCustomer(){
      logger.info("An INFO Message");
   }

   public void findCustomerById(){
      logger.warn("A WARN Message");
   }

   public void findCustomersByName(){
      logger.error("An ERROR Message");
   }
}
```

The application

```
@SpringBootApplication
public class CustomerApplication implements CommandLineRunner {

  @Autowired
  private CustomerService customerService;


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

  @Override
  public void run(String... args) throws Exception {
    customerService.addCustomer();
    customerService.updateCustomer();
    customerService.removeCustomer();
    customerService.findCustomerById();
    customerService.findCustomersByName();
  }
}
```

The output

```
  .   ____          _            __ _ _
 /\\ / ___'_ __ _ _(_)_ __  __ _ \ \ \ \
( ( )\___ | '_ | '_| | '_ \/ _` | \ \ \ \
 \\/  ___)| |_)| | | | | || (_| |  ) ) ) )
  '  |____| .__|_| |_|_| |_\__, | / / / /
 =========|_|==============|___/=/_/_/_/
 :: Spring Boot ::                (v2.5.4)

2022-07-05 13:32:45.706  INFO 1948 --- [           main] app.CustomerApplication                  : Starting CustomerApplication using Java
 11.0.1 on DESKTOP-BVHRK6K with PID 1948 (C:\EnterpriseArchiteture\demo code\Lesson13Logging\target\classes started by vedam in
 C:\EnterpriseArchiteture\demo code\Lesson13Logging)
2022-07-05 13:32:45.708  INFO 1948 --- [           main] app.CustomerApplication                  : No active profile set, falling back to
 default profiles: default
2022-07-05 13:32:46.216  INFO 1948 --- [           main] app.CustomerApplication                  : Started CustomerApplication in 0.936
 seconds (JVM running for 1.381)
2022-07-05 13:32:46.218  INFO 1948 --- [           main] app.CustomerService                      : An INFO Message
2022-07-05 13:32:46.218  WARN 1948 --- [           main] app.CustomerService                      : A WARN Message
2022-07-05 13:32:46.218 ERROR 1948 --- [           main] app.CustomerService                      : An ERROR Message
```

Default logging to the console

Default logging level is INFO

Logging level

- TRACE: gives detailed information about the code
- DEBUG: gives more specific diagnostic information that you need during debugging
- INFO (default level): gives high level information
- WARN: potential problems that might cause problems
- ERROR: serious issues like exceptions

Logging level

Default logging level is INFO

```
#logging.level.root=DEBUG
```

```
2022-07-05 12:18:51.737  INFO 29548 --- [           main] app.CustomerService                      : An INFO Message
2022-07-05 12:18:51.737  WARN 29548 --- [           main] app.CustomerService                      : A WARN Message
2022-07-05 12:18:51.737 ERROR 29548 --- [           main] app.CustomerService                      : An ERROR Message
```

```
logging.level.root=WARN
```

```
2022-07-05 12:19:52.173  WARN 2692 --- [           main] app.CustomerService                       : A WARN Message
2022-07-05 12:19:52.175 ERROR 2692 --- [           main] app.CustomerService                       : An ERROR Message
```

```
logging.level.root=ERROR
```

```
2022-07-05 12:20:57.133 ERROR 3560 --- [           main] app.CustomerService                      : An ERROR Message
```

Logging level

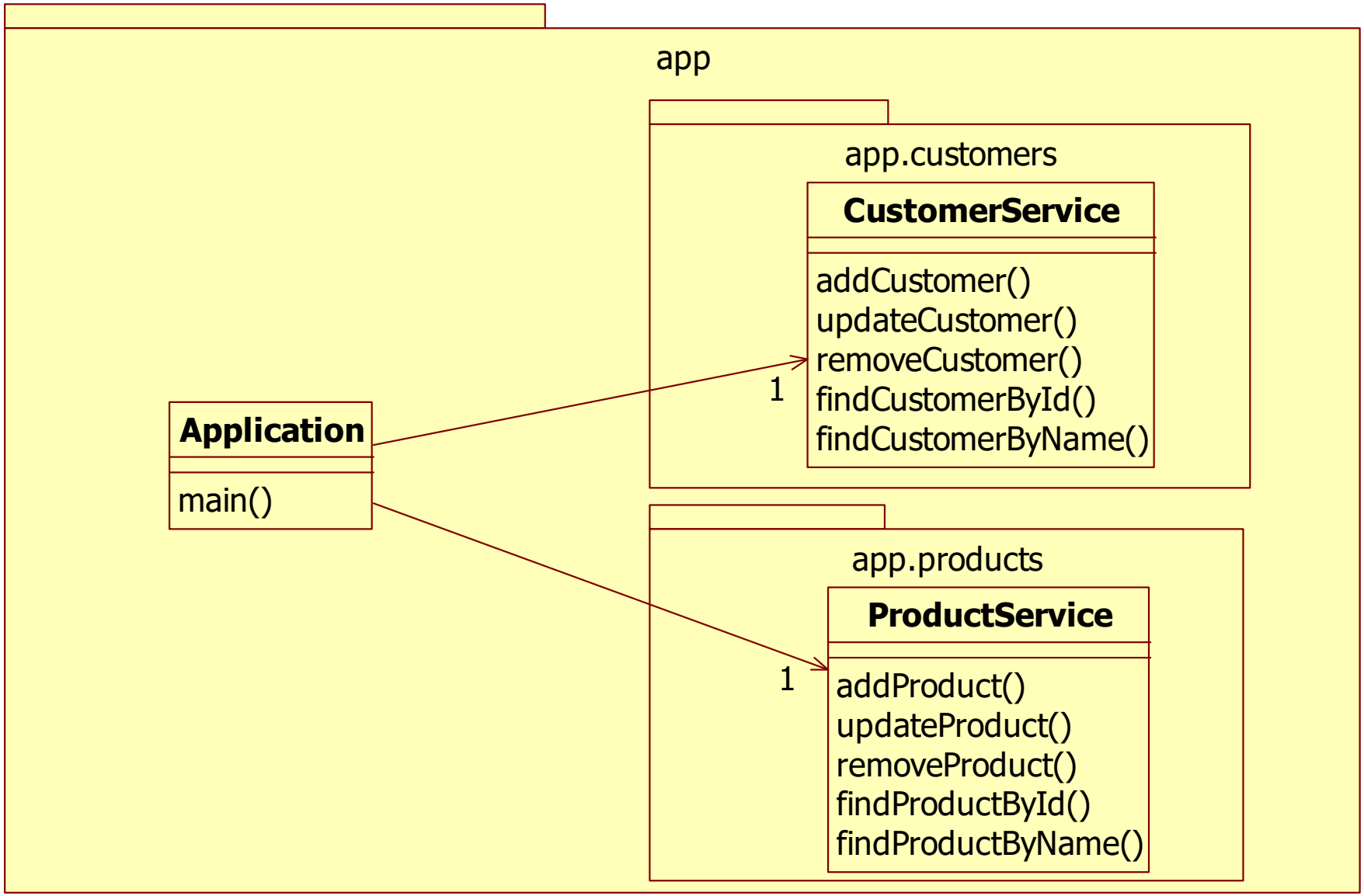
```
logging.level.root=DEBUG
```

```
2022-07-05 12:16:15.581 DEBUG 29812 --- [           main] app.CustomerService                      : A DEBUG Message
2022-07-05 12:16:15.581  INFO 29812 --- [           main] app.CustomerService                      : An INFO Message
2022-07-05 12:16:15.581  WARN 29812 --- [           main] app.CustomerService                      : A WARN Message
2022-07-05 12:16:15.581 ERROR 29812 --- [           main] app.CustomerService                      : An ERROR Message
```

```
logging.level.root=TRACE
```

```
2022-07-05 12:13:47.372 TRACE 8380 --- [           main] app.CustomerService                      : A TRACE Message
2022-07-05 12:13:47.372 DEBUG 8380 --- [           main] app.CustomerService                      : A DEBUG Message
2022-07-05 12:13:47.372  INFO 8380 --- [           main] app.CustomerService                      : An INFO Message
2022-07-05 12:13:47.372  WARN 8380 --- [           main] app.CustomerService                      : A WARN Message
2022-07-05 12:13:47.372 ERROR 8380 --- [           main] app.CustomerService                      : An ERROR Message
```

Logging level on packages

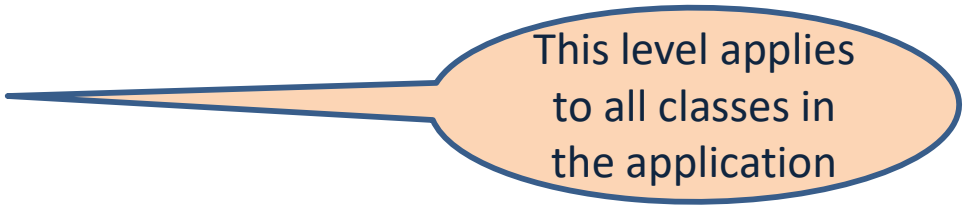


The application

```
@SpringBootApplication
public class Application implements CommandLineRunner {
  @Autowired
  private CustomerService customerService;
  @Autowired
  private ProductService productService;

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

  @Override
  public void run(String... args) throws Exception {
    Logger logger = LoggerFactory.getLogger(Application.class);
    logger.info("An INFO Message");
    logger.error("An ERROR Message");

    customerService.addCustomer();
    customerService.updateCustomer();
    customerService.removeCustomer();
    customerService.findCustomerById();
    customerService.findCustomersByName();

    productService.addProduct();
    productService.updateProduct();
    productService.removeProduct();
    productService.findProductById();
    productService.findProductByName();
  }
}
```

Logging level on packages

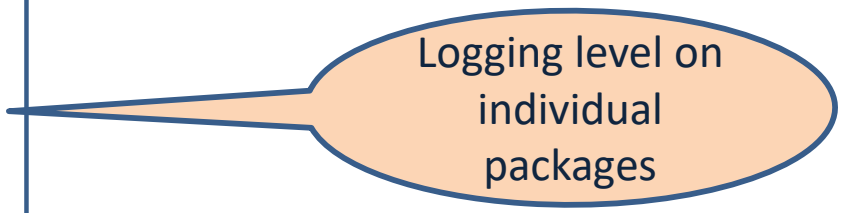
```
logging.level.root=INFO
```




```
2022-07-05 19:10:59.036  INFO 29528 --- [           main] app.Application                          : An INFO Message
2022-07-05 19:10:59.036 ERROR 29528 --- [           main] app.Application                          : An ERROR Message
2022-07-05 19:10:59.036  INFO 29528 --- [           main] app.customers.CustomerService            : An INFO Message
2022-07-05 19:10:59.036  WARN 29528 --- [           main] app.customers.CustomerService            : A WARN Message
2022-07-05 19:10:59.036 ERROR 29528 --- [           main] app.customers.CustomerService            : An ERROR Message
2022-07-05 19:10:59.036  INFO 29528 --- [           main] app.products.ProductService              : An INFO Message
2022-07-05 19:10:59.036  WARN 29528 --- [           main] app.products.ProductService              : A WARN Message
2022-07-05 19:10:59.036 ERROR 29528 --- [           main] app.products.ProductService              : An ERROR Message
```

Logging level on packages

```
logging.level.root=INFO
logging.level.app.customers=ERROR
logging.level.app.products=TRACE
```




```
2022-07-05 19:21:21.497  INFO 30568 --- [           main] app.Application                          : An INFO Message
2022-07-05 19:21:21.497 ERROR 30568 --- [           main] app.Application                          : An ERROR Message
2022-07-05 19:21:21.497 ERROR 30568 --- [           main] app.customers.CustomerService            : An ERROR Message
2022-07-05 19:21:21.497 TRACE 30568 --- [           main] app.products.ProductService              : A TRACE Message
2022-07-05 19:21:21.497 DEBUG 30568 --- [           main] app.products.ProductService              : A DEBUG Message
2022-07-05 19:21:21.497  INFO 30568 --- [           main] app.products.ProductService              : An INFO Message
2022-07-05 19:21:21.497  WARN 30568 --- [           main] app.products.ProductService              : A WARN Message
2022-07-05 19:21:21.497 ERROR 30568 --- [           main] app.products.ProductService              : An ERROR Message
```

Log format

```
2022-07-05 12:13:47.372 TRACE 8380 --- [           main] app.CustomerService                      : A TRACE Message
2022-07-05 12:13:47.372 DEBUG 8380 --- [           main] app.CustomerService                      : A DEBUG Message
2022-07-05 12:13:47.372  INFO 8380 --- [           main] app.CustomerService                      : An INFO Message
2022-07-05 12:13:47.372  WARN 8380 --- [           main] app.CustomerService                      : A WARN Message
2022-07-05 12:13:47.372 ERROR 8380 --- [           main] app.CustomerService                      : An ERROR Message
```

1 2 3 4 5 6 7

1. Date and Time
2. Log level
3. Process ID
4. The separator ---
5. Thread name
6. Logger name source class
7. Log message

Change Log format

```
logging.level.root=INFO

logging.pattern.console= %d{yyyy-MM-dd HH:mm:ss} - %logger - %msg%n
logging.pattern.file=%d{yyyy-MM-dd HH:mm:ss} - %logger - %msg%n
```

```
2022-07-05 12:37:13 - app.CustomerService - An INFO Message
2022-07-05 12:37:13 - app.CustomerService - A WARN Message
2022-07-05 12:37:13 - app.CustomerService - An ERROR Message
```

Change Log format

```
logging.level.root=INFO

logging.pattern.console= %d{yyyy-MM-dd HH:mm:ss} - %logger - %msg%n
logging.pattern.file=%d{yyyy-MM-dd HH:mm:ss} - %logger - %msg%n
```

```
2022-07-05 12:37:13 - app.CustomerService - An INFO Message
2022-07-05 12:37:13 - app.CustomerService - A WARN Message
2022-07-05 12:37:13 - app.CustomerService - An ERROR Message
```

```
logging.pattern.console= %d{yyyy-MM-dd HH:mm:ss} [%thread] %level %logger - %msg%n
logging.pattern.file= %d{yyyy-MM-dd HH:mm:ss} [%thread] %level %logger - %msg%n
```

```
2022-07-05 12:46:26 [main] INFO app.CustomerService - An INFO Message
2022-07-05 12:46:26 [main] WARN app.CustomerService - A WARN Message
2022-07-05 12:46:26 [main] ERROR app.CustomerService - An ERROR Message
```

Logging to a file

```
logging.file.name=c:/temp/application.log
```

C:\temp\application.log

```
2022-07-05 13:52:49.002  INFO 5640 --- [main] app.CustomerApplication                : Starting
CustomerApplication using Java 11.0.1 on DESKTOP-BVHRK6K with PID 5640 (C:\EnterpriseArchiteture\demo
code\Lesson13Logging\target\classes started by vedam in C:\EnterpriseArchiteture\demo code\Lesson13Logging)
2022-07-05 13:52:49.005  INFO 5640 --- [main] app.CustomerApplication                : No active profile set,
falling back to default profiles: default
2022-07-05 13:52:49.628  INFO 5640 --- [main] app.CustomerApplication                : Started
CustomerApplication in 1.141 seconds (JVM running for 1.569)
2022-07-05 13:52:49.634  INFO 5640 --- [main] app.CustomerService                    : An INFO Message
2022-07-05 13:52:49.634  WARN 5640 --- [main] app.CustomerService                    : A WARN Message
2022-07-05 13:52:49.634 ERROR 5640 --- [main] app.CustomerService                    : An ERROR Message
```

Logging to a file

```
logging.file.path=c:/temp/logs
```

C:\temp\logs\spring.log

```
2022-07-05 13:52:49.002  INFO 5640 --- [main] app.CustomerApplication                : Starting
CustomerApplication using Java 11.0.1 on DESKTOP-BVHRK6K with PID 5640 (C:\EnterpriseArchiteture\demo
code\Lesson13Logging\target\classes started by vedam in C:\EnterpriseArchiteture\demo code\Lesson13Logging)
2022-07-05 13:52:49.005  INFO 5640 --- [main] app.CustomerApplication                : No active profile set,
falling back to default profiles: default
2022-07-05 13:52:49.628  INFO 5640 --- [main] app.CustomerApplication                : Started
CustomerApplication in 1.141 seconds (JVM running for 1.569)
2022-07-05 13:52:49.634  INFO 5640 --- [main] app.CustomerService                    : An INFO Message
2022-07-05 13:52:49.634  WARN 5640 --- [main] app.CustomerService                    : A WARN Message
2022-07-05 13:52:49.634 ERROR 5640 --- [main] app.CustomerService                    : An ERROR Message
```

ACTUATORS

/actuator


```
{"_links":{"self":{"href":"http://localhost:8080/actuator","templated":false},"beans":
{"href":"http://localhost:8080/actuator/beans","templated":false},"caches-cache":
{"href":"http://localhost:8080/actuator/caches/{cache}","templated":true},"caches":
{"href":"http://localhost:8080/actuator/caches","templated":false},"health":
{"href":"http://localhost:8080/actuator/health","templated":false},"health-path":
{"href":"http://localhost:8080/actuator/health/{*path}","templated":true},"info":
{"href":"http://localhost:8080/actuator/info","templated":false},"conditions":
{"href":"http://localhost:8080/actuator/conditions","templated":false},"shutdown":
{"href":"http://localhost:8080/actuator/shutdown","templated":false},"configprops":
{"href":"http://localhost:8080/actuator/configprops","templated":false},"configprops-prefix":
{"href":"http://localhost:8080/actuator/configprops/{prefix}","templated":true},"env":
{"href":"http://localhost:8080/actuator/env","templated":false},"env-toMatch":
{"href":"http://localhost:8080/actuator/env/{toMatch}","templated":true},"loggers":
{"href":"http://localhost:8080/actuator/loggers","templated":false},"loggers-name":
{"href":"http://localhost:8080/actuator/loggers/{name}","templated":true},"heapdump":
{"href":"http://localhost:8080/actuator/heapdump","templated":false},"threaddump":
{"href":"http://localhost:8080/actuator/threaddump","templated":false},"metrics-requiredMetricName":
{"href":"http://localhost:8080/actuator/metrics/{requiredMetricName}","templated":true},"metrics":
{"href":"http://localhost:8080/actuator/metrics","templated":false},"scheduledtasks":
{"href":"http://localhost:8080/actuator/scheduledtasks","templated":false},"mappings":
{"href":"http://localhost:8080/actuator/mappings","templated":false}}}
```

Actuator

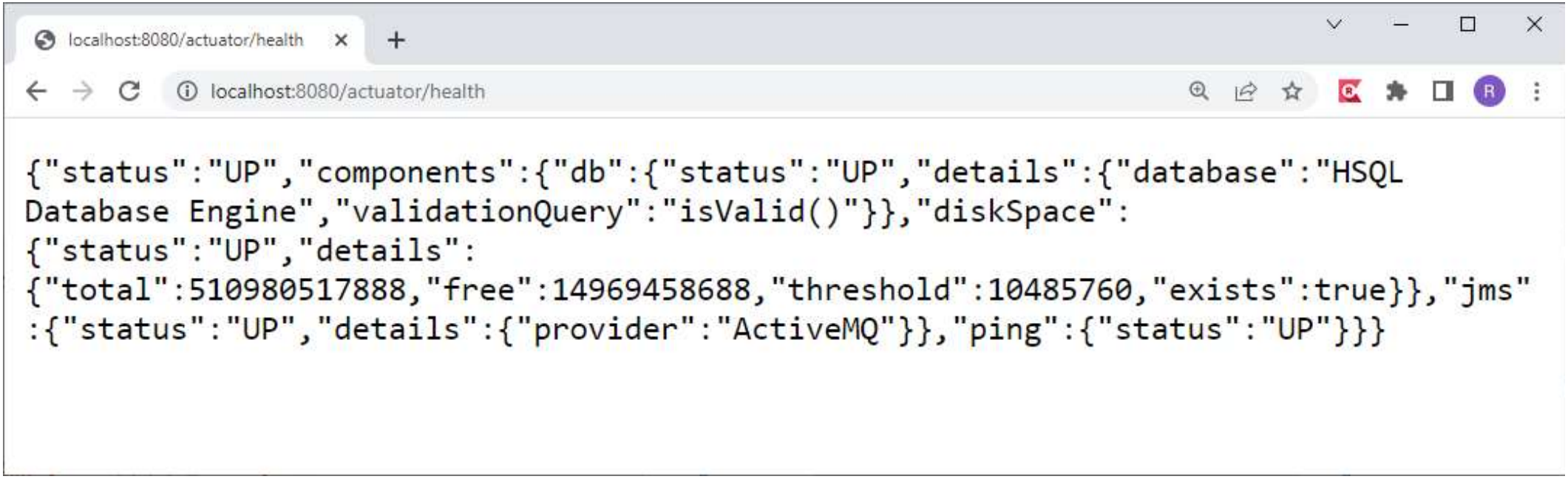
- Actuator brings production-ready features to our application

```
<dependency>
  <groupId>org.springframework.boot</groupId>
  <artifactId>spring-boot-starter-actuator</artifactId>
</dependency>
```

- Once this dependency is on the classpath several endpoints are available for us out of the box.
- You can modify existing actuators and you can write you own actuators

/actuator/health

This is all that is shown by default




```
management.endpoint.health.show-details=ALWAYS
```

Show all health information

Exposing actuators

- Only the /health actuator is exposed by default

- Exposing particular actuators

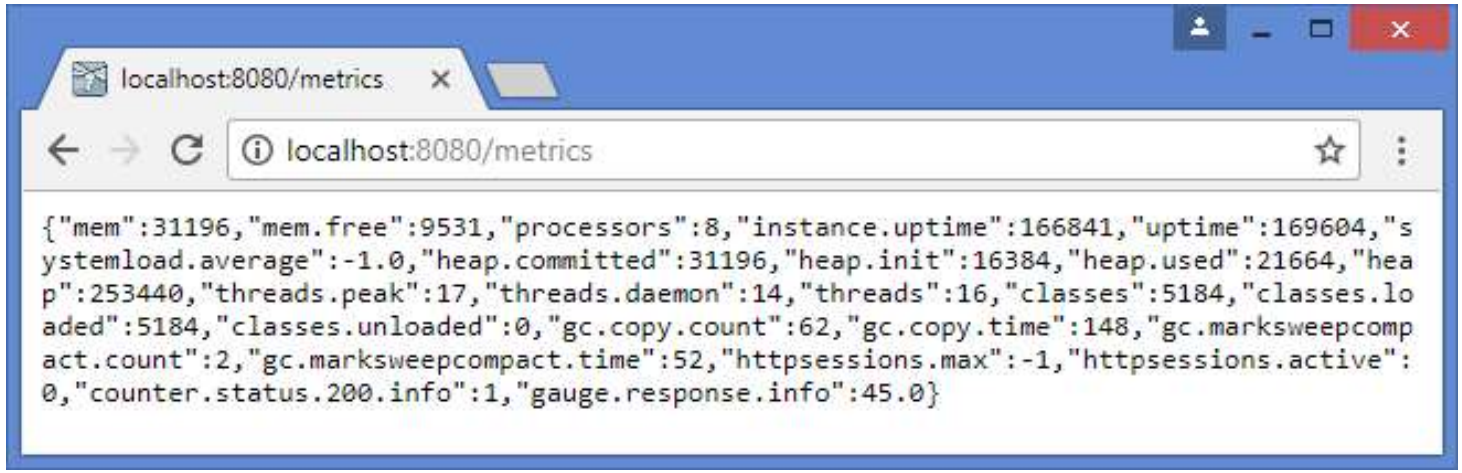
```
management.endpoints.web.exposure.include=beans,mappings
```

- Exposing all actuators

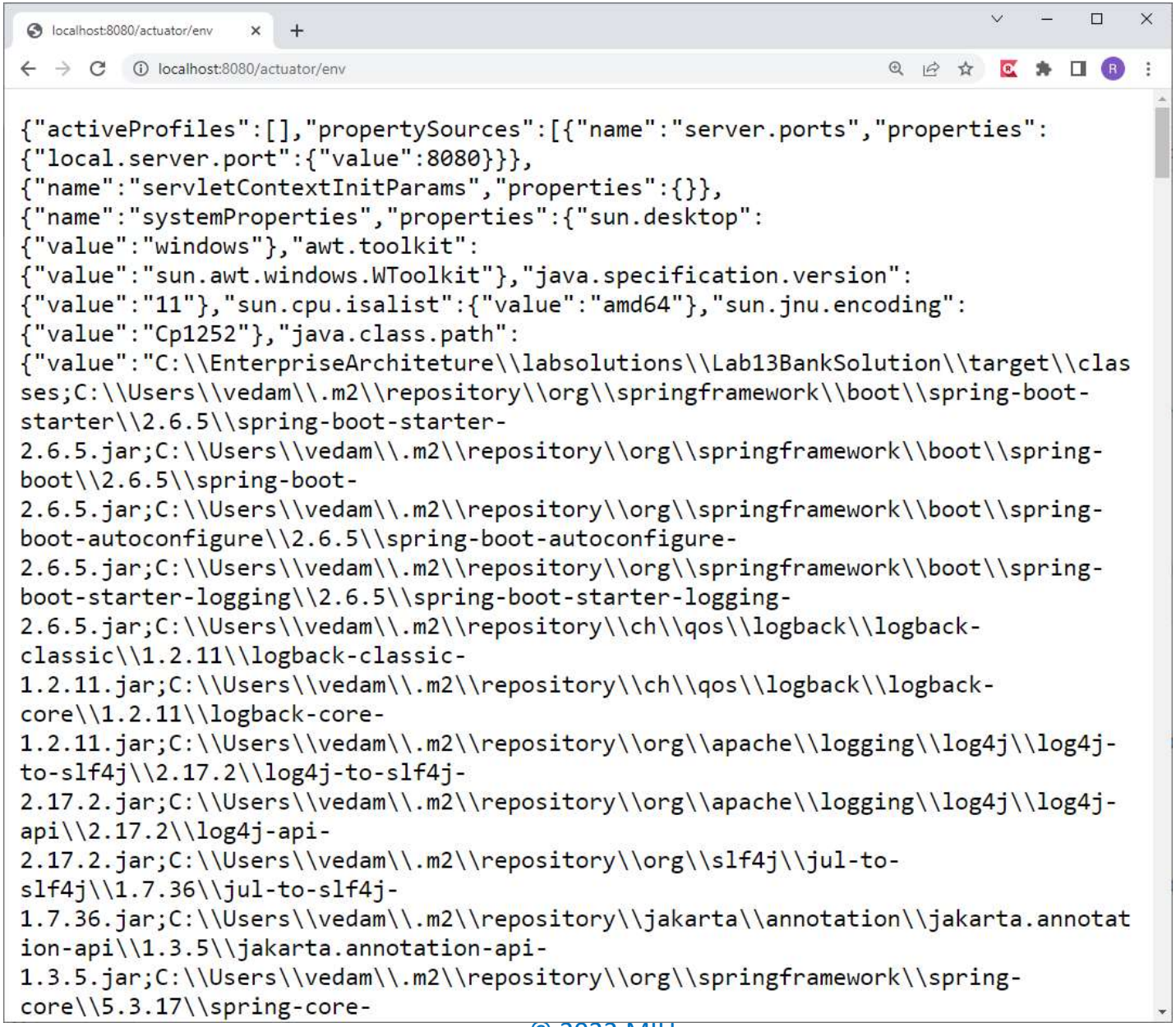
```
management.endpoints.web.exposure.include=*
```

/actuator/metrics

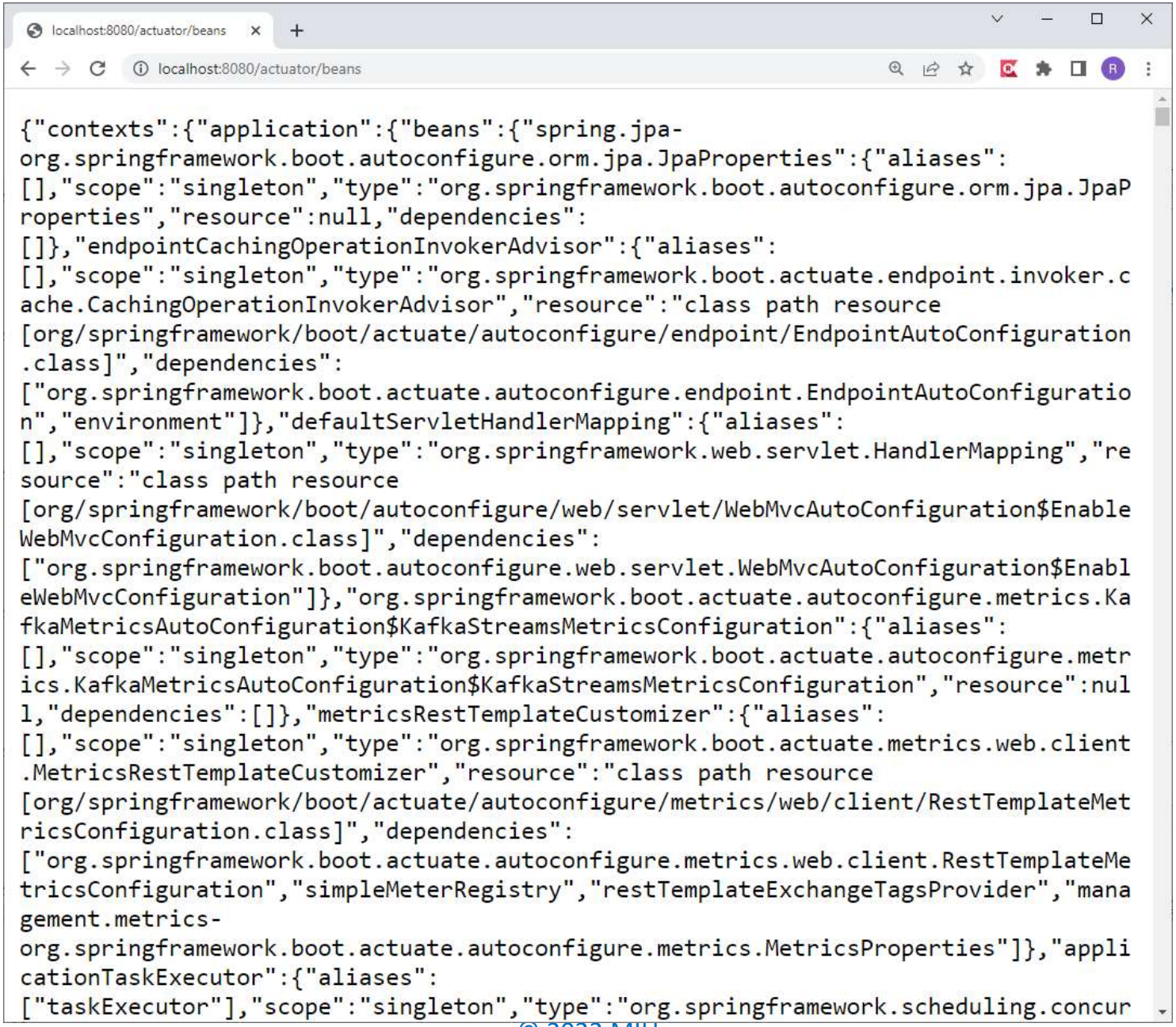
- Gives information such as memory, heap, processors, threads, classes loaded, classes unloaded, thread pools along with some HTTP metrics as well



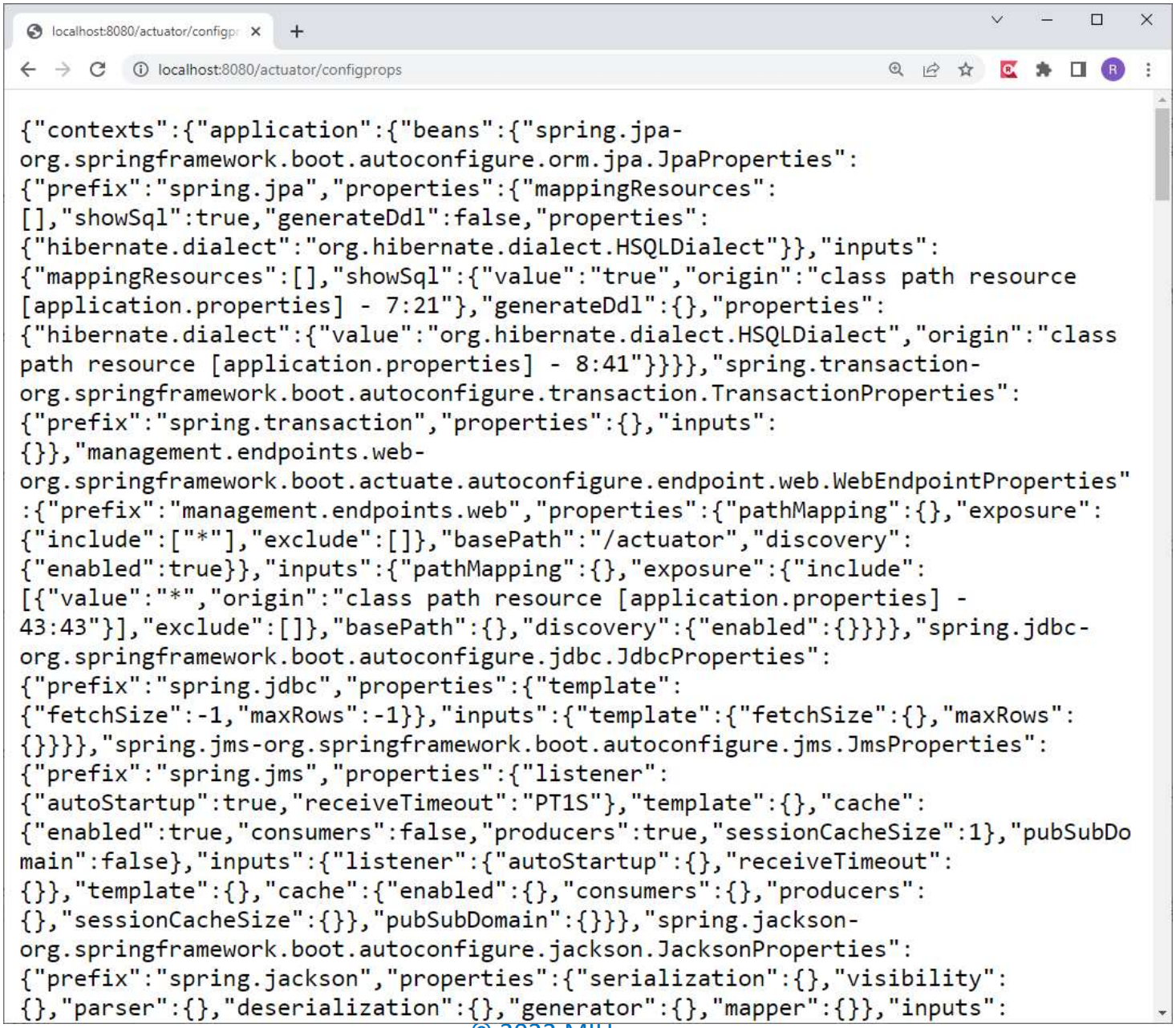
/actuator/env



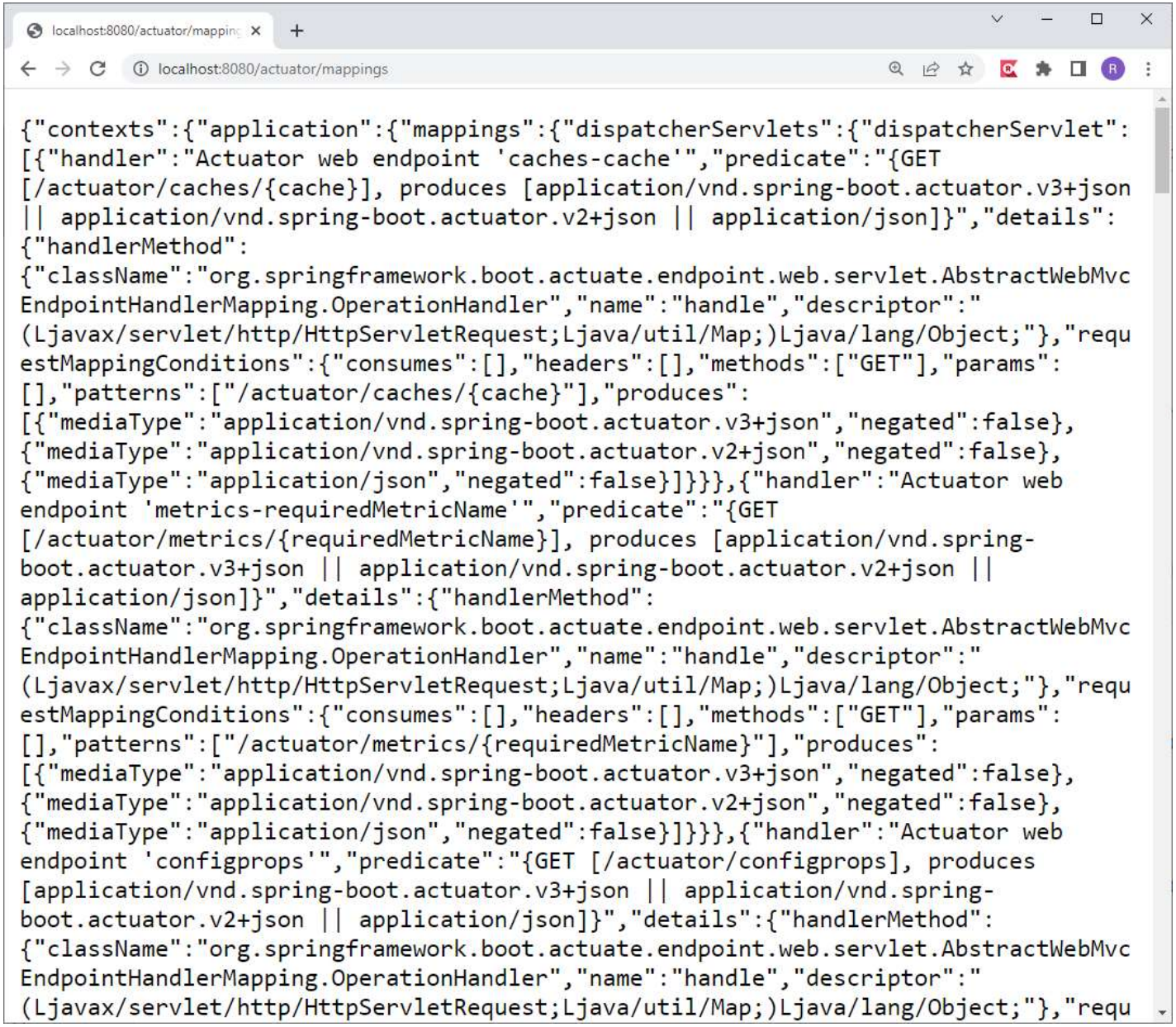
/actuator/beans



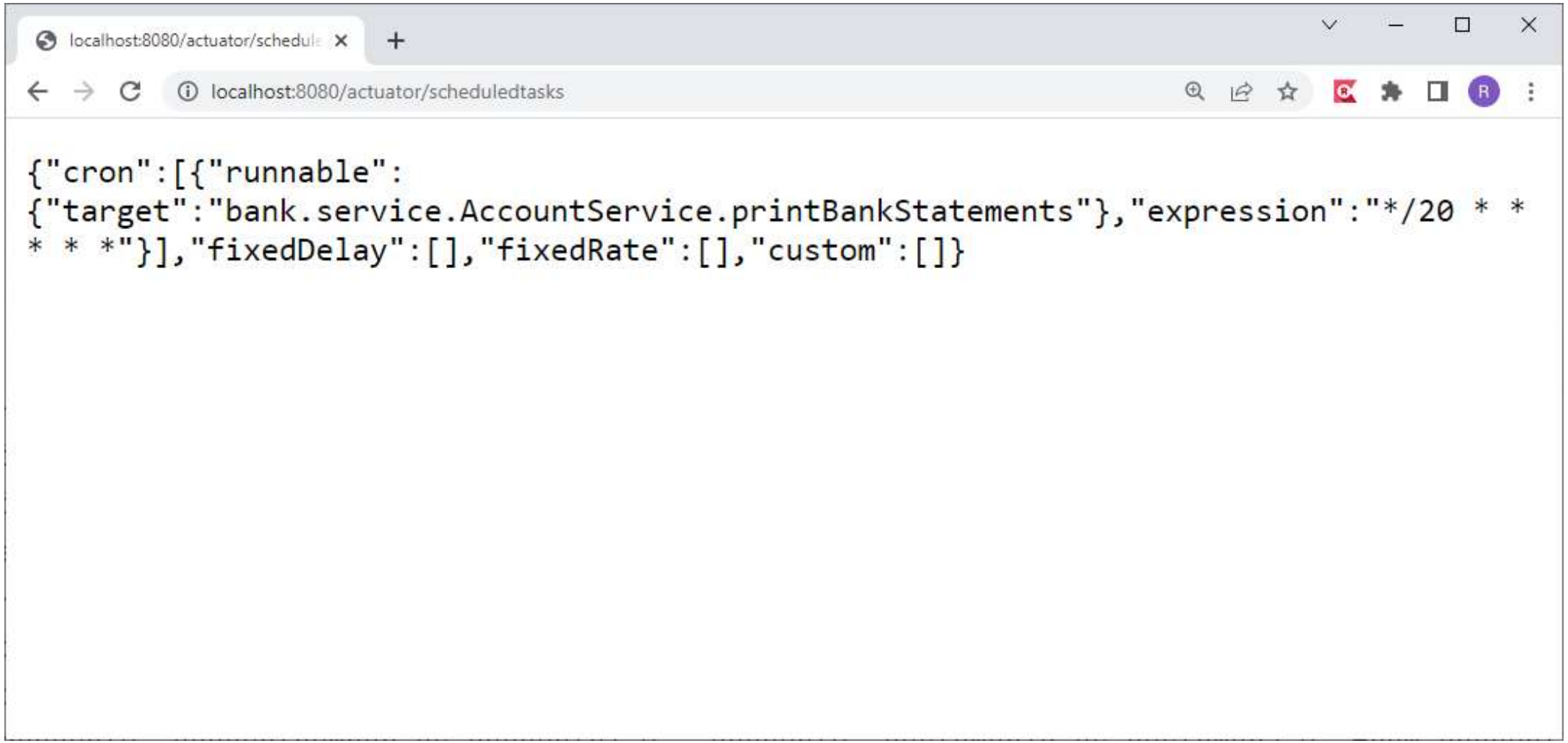
/actuator/configprops



/actuator/mappings



/actuator/scheduledtasks



Available actuators

GET	/autoconfig	Provides an auto-configuration report describing what auto-configuration conditions passed and failed.
GET	/configprops	Describes how beans have been injected with configuration properties (including default values).
GET	/beans	Describes all beans in the application context and their relationship to each other.
GET	/dump	Retrieves a snapshot dump of thread activity.
GET	/env	Retrieves all environment properties.

Available actuators

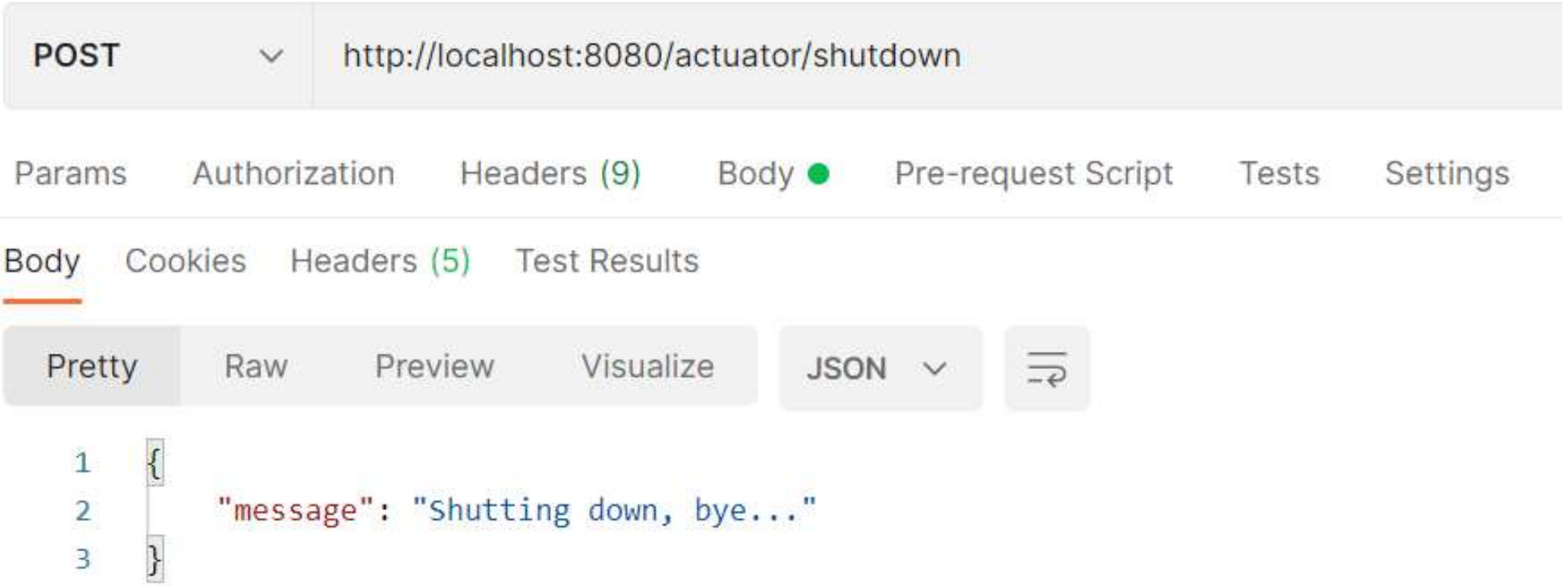
GET	/env/{name}	Retrieves a specific environment value by name.
GET	/health	Reports health metrics for the application, as provided by HealthIndicator implementations.
GET	/info	Retrieves custom information about the application, as provided by any properties prefixed with info.
GET	/mappings	Describes all URI paths and how they're mapped to controllers (including Actuator endpoints).
GET	/metrics	Reports various application metrics such as memory usage and HTTP request counters.

Available actuators

GET	/metrics/{name}	Reports an individual application metric by name.
POST	/shutdown	Shuts down the application; requires that endpoints.shutdown.enabled be set to true.
GET	/trace	Provides basic trace information (timestamp, headers, and so on) for HTTP requests.

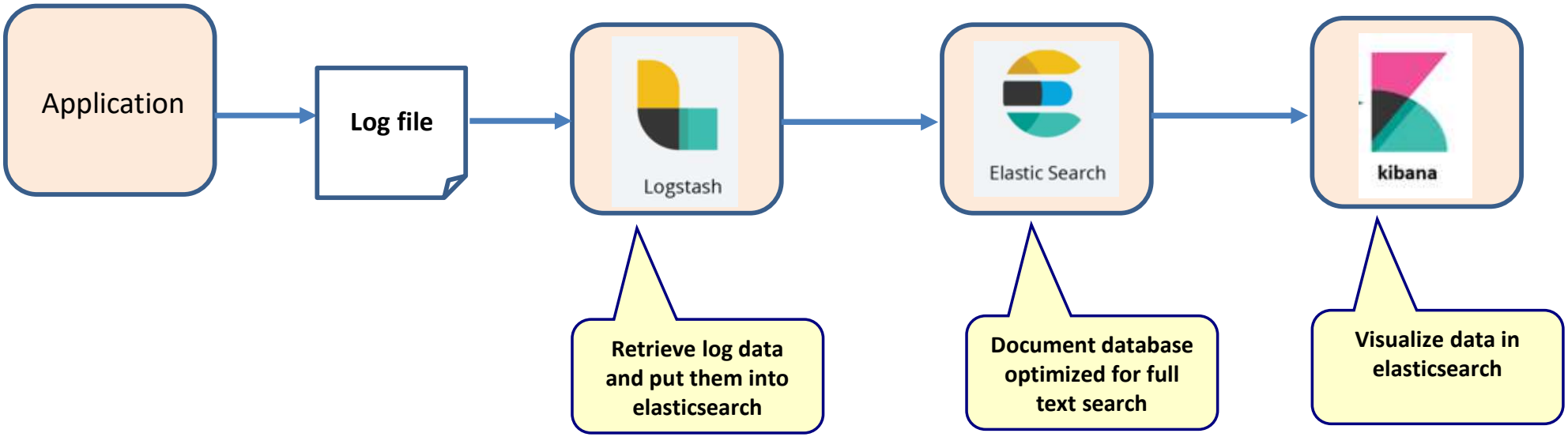
shutdown

```
management.endpoint.shutdown.enabled=true
```



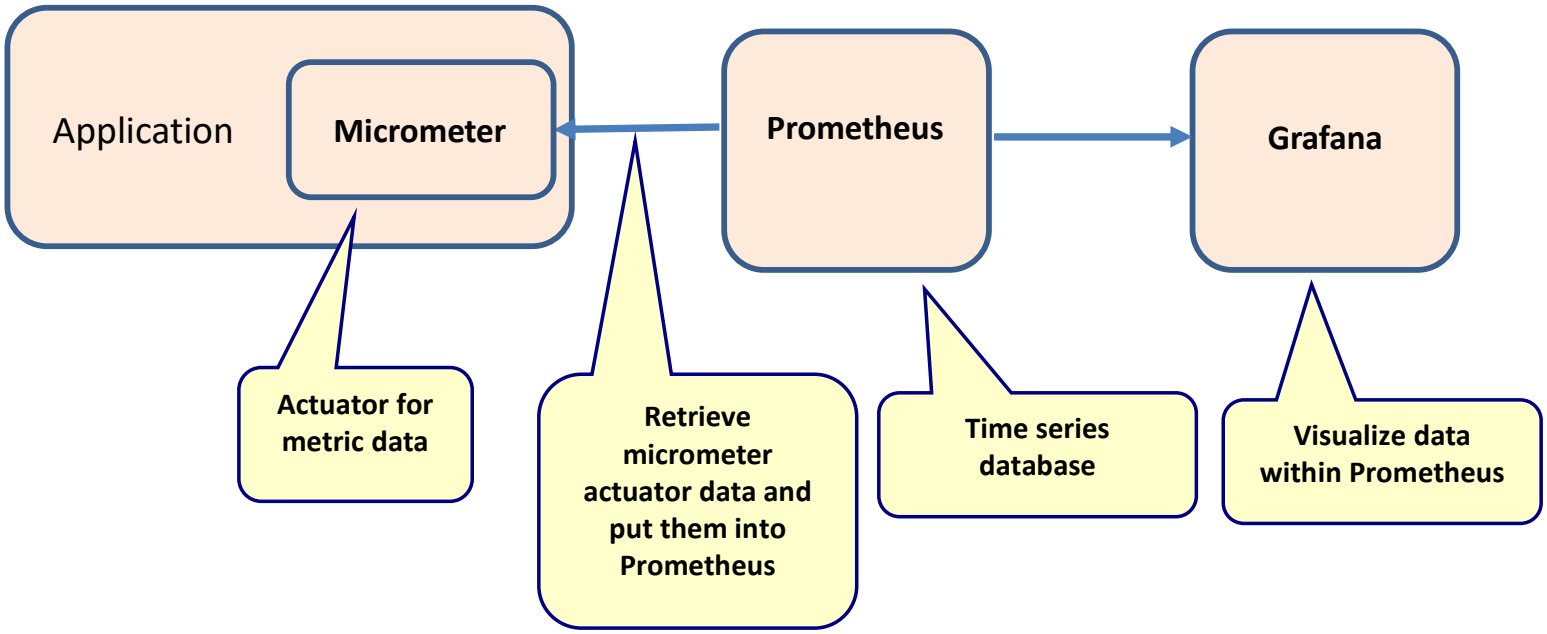
APPLICATION MONITORING

Approach 1: ELK stack



- Good for application specific log data

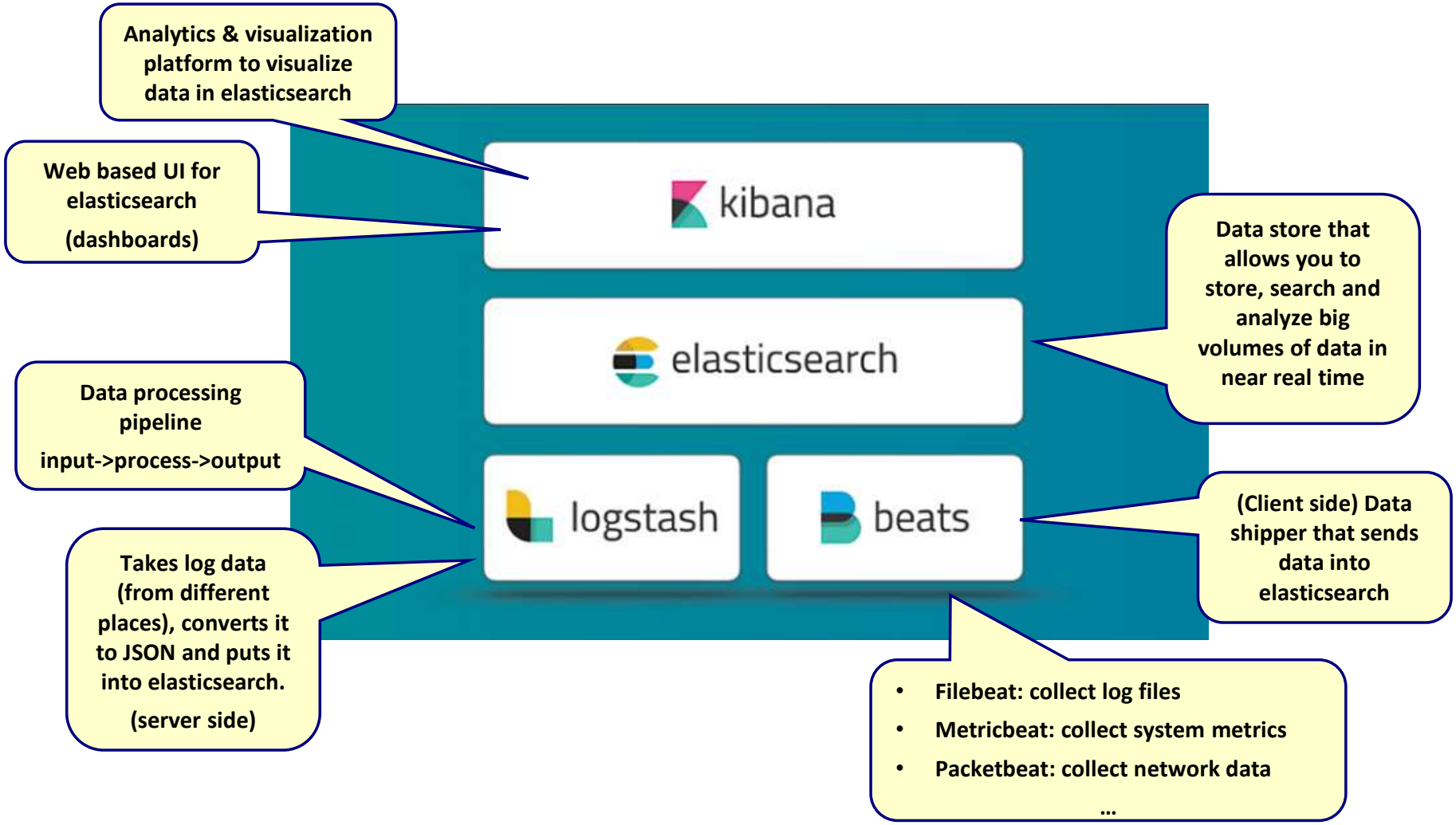
Approach 2: Prometheus/Grafana



- Good for metric data
  - Memory usage
  - CPU usage
  - JVM specific data

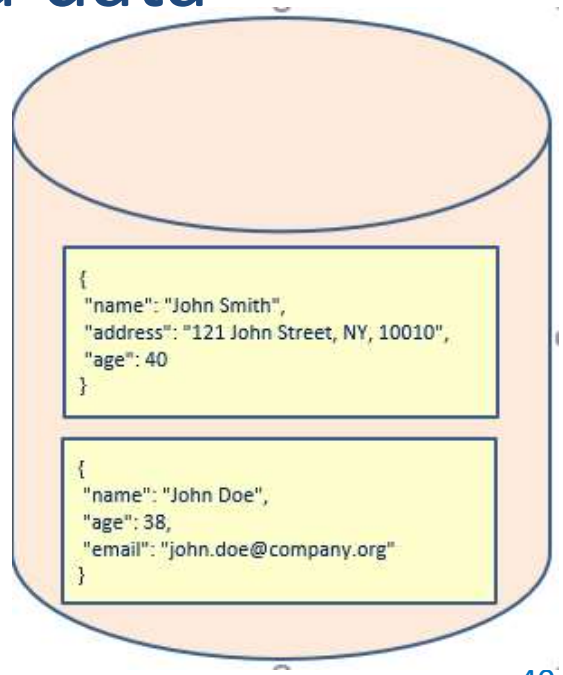
THE ELASTIC STACK

Elastic stack components

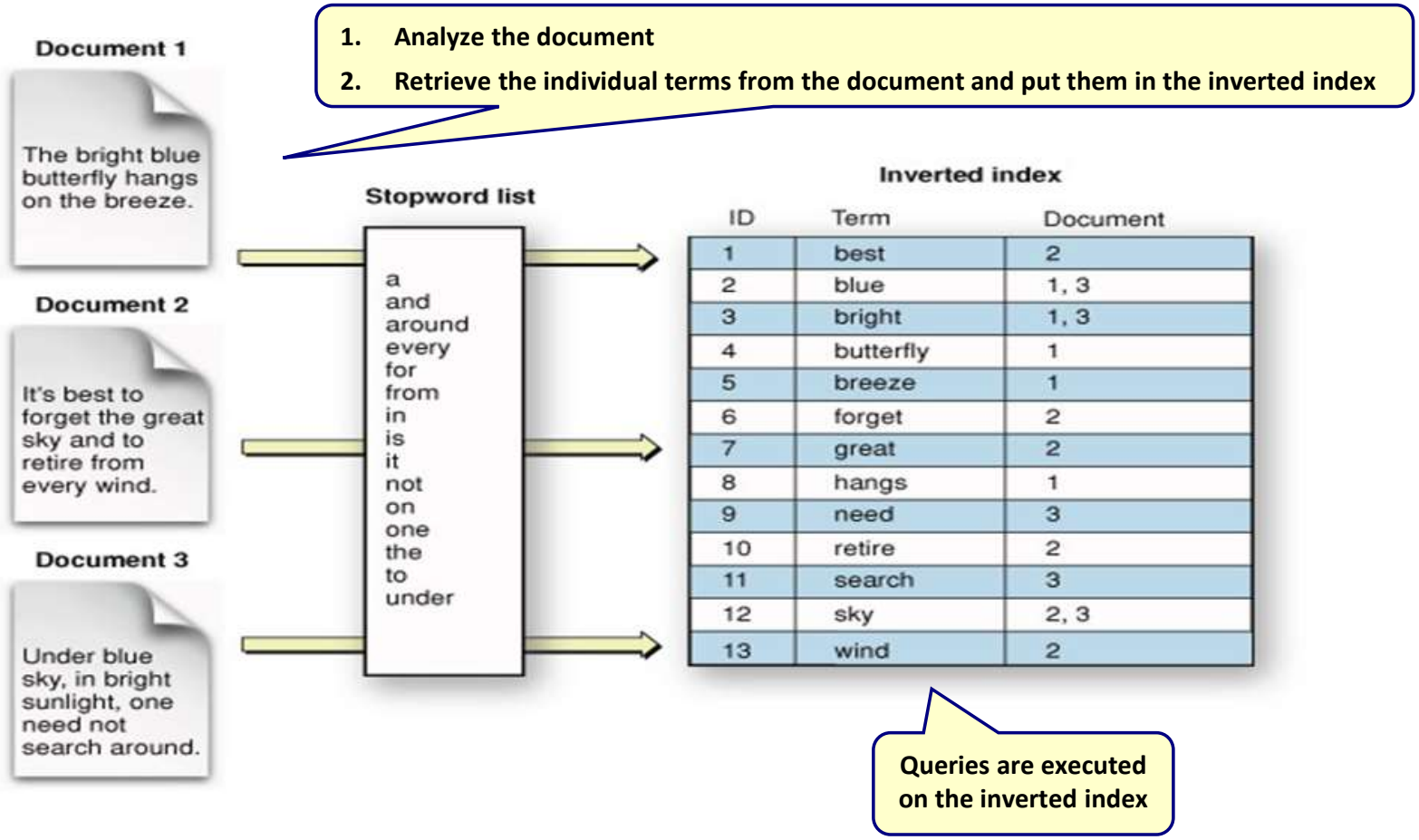


What is Elasicsearch?

- Database
  - Data is stored as documents
  - Data is structured in JSON format
- Full text search engine
- Analytics platform for structured data



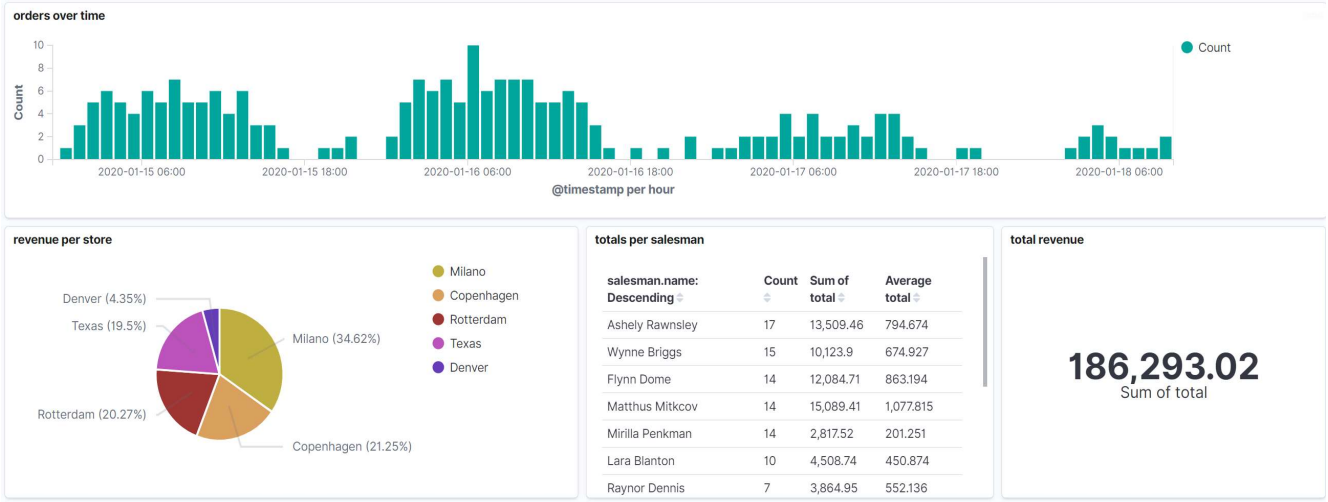
Inverted index



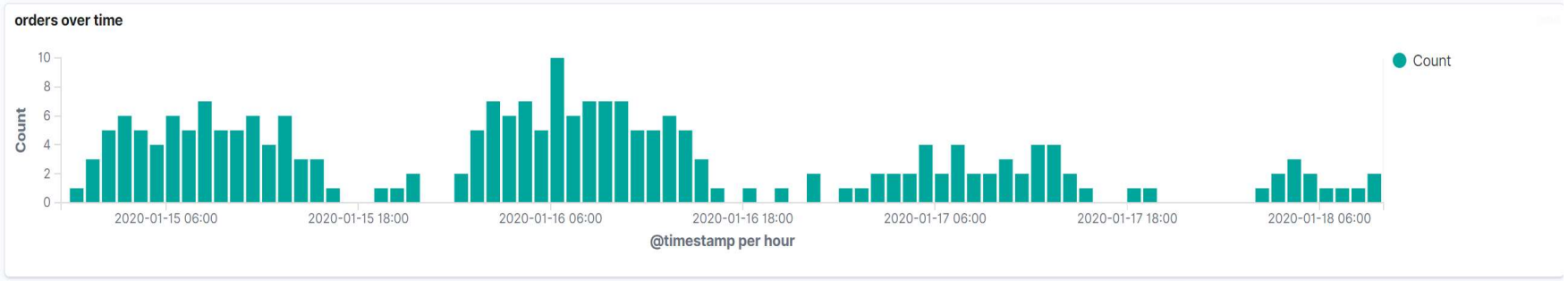
KIBANA

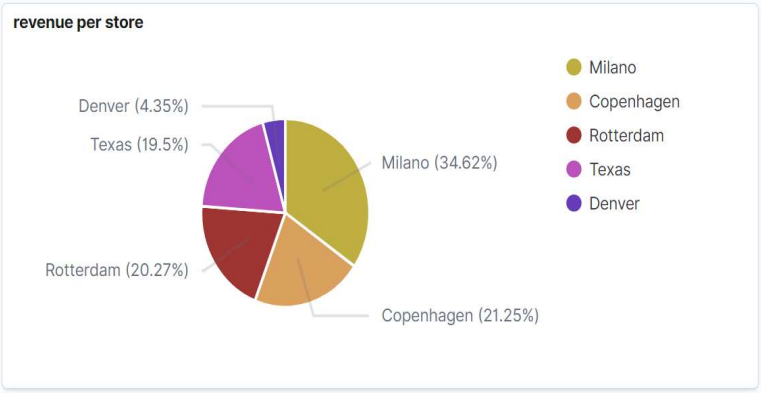
Kibana

- Web UI on top of elasticsearch
- Has its own Kibana query language (KQL)
- Objects (Queries, visualizations, dashboards, etc.) are saved in elasticsearch



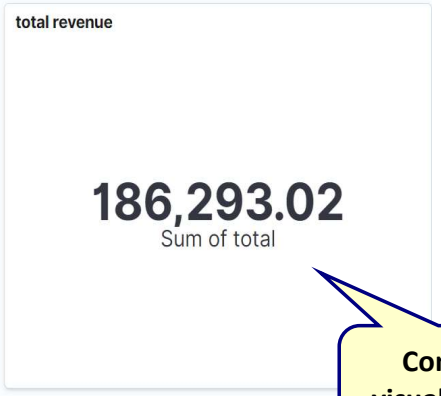
Dashboard





totals per salesman

salesman.name: Descending	Count	Sum of total	Average total
Ashely Rawnsley	17	13,509.46	794.674
Wynne Briggs	15	10,123.9	674.927
Flynn Dome	14	12,084.71	863.194
Matthus Mitkcov	14	15,089.41	1,077.815
Mirilla Penkman	14	2,817.52	201.251
Lara Blanton	10	4,508.74	450.874
Raynor Dennis	7	3,864.95	552.136

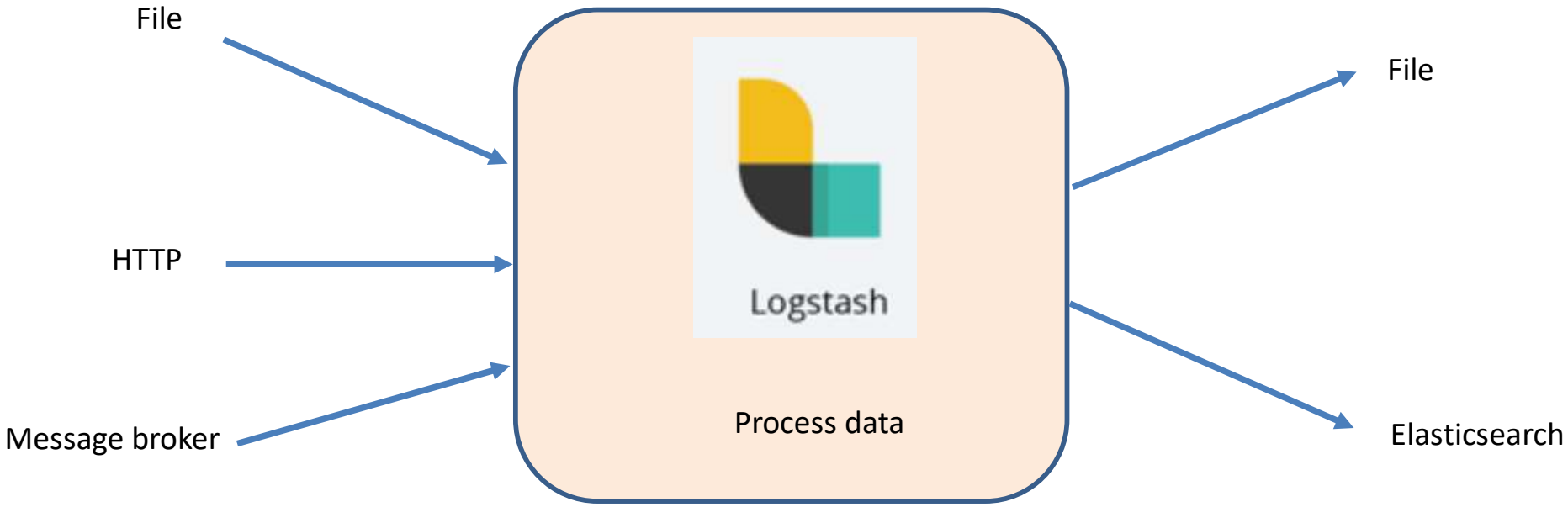


Contains visualizations

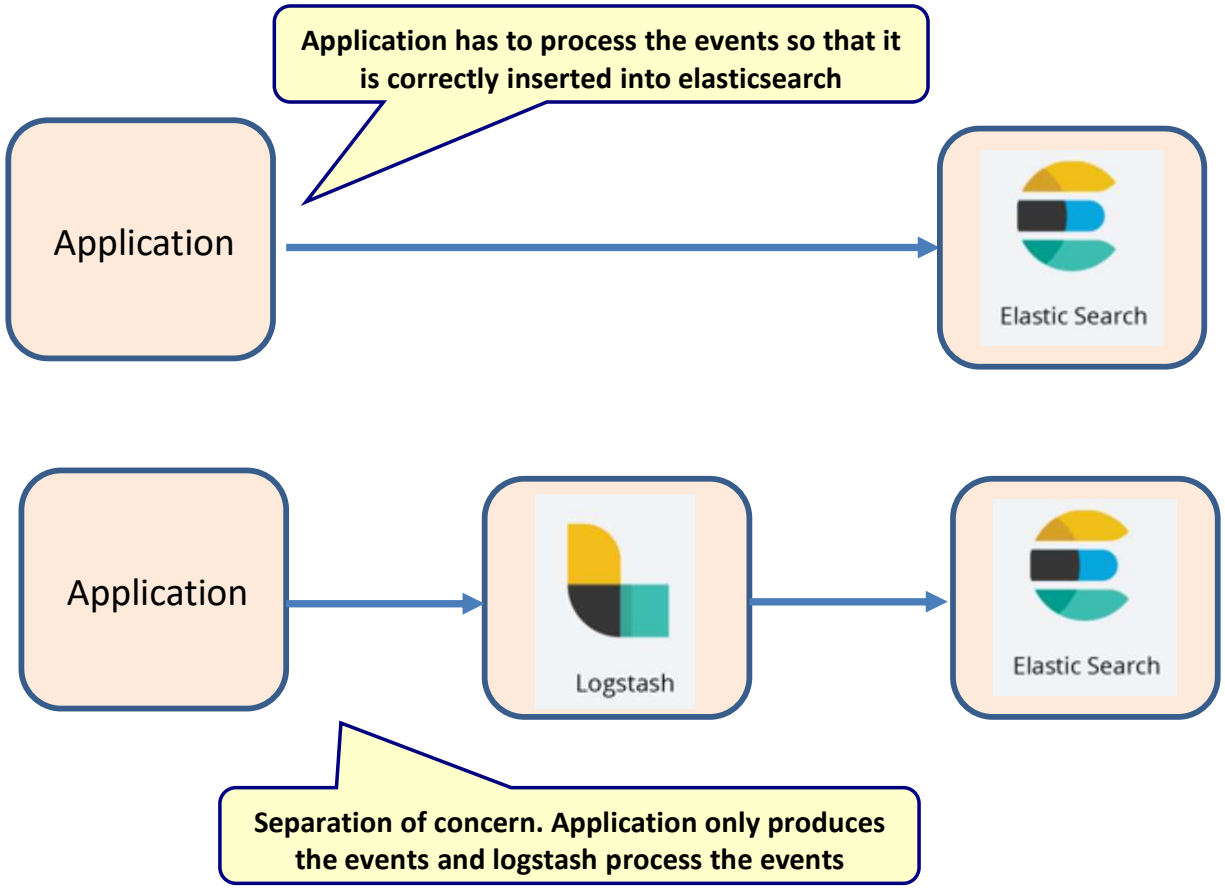
LOGSTASH

Logstash

- Event processing engine



Why logstash in ELK?



Logstash configuration

input.txt

```
Hello world
```

pipeline.conf

```
input {
  file {
    path => "C:/elasticsearchtraining/temp/input.txt"
    start_position => "beginning"
  }
}

output {
  stdout {
    codec => rubydebug
  }
  file {
    path => "C:/elasticsearchtraining/temp/output.txt"
  }
}
```

output.txt

```
{
"host":"DESKTOP-BVHRK6K",
"@version":"1",
"path":"C:/elasticsearchtraining/temp/input.txt",
"message":"Hello world\r",
"@timestamp":"2021-01-16T13:52:32.726Z"
}
```

Anytime this file changes, read from this file

Write the output to the console

Write the output to the specified file

Logstash configuration

input.txt

```
Hi there
```

pipeline.conf

```
input {
 file {
   path => "C:/elasticsearchtraining/temp/input.txt"
          start_position => "beginning"
 }
}

filter {
   mutate {
      uppercase => ["message"]
   }
}

output {
 stdout {
   codec => rubydebug
 }
 file {
   path => "C:/elasticsearchtraining/temp/output.txt"
 }
}
```

output.txt

```
{
"path":"C:/elasticsearchtraining/temp/input.txt",
"message":"HI THERE\r",
"host":"DESKTOP-BVHRK6K",
"@version":"1",
"@timestamp":"2021-01-16T14:17:10.537Z"
}
```

Logstash configuration

input.txt

```
get 2500 300
```

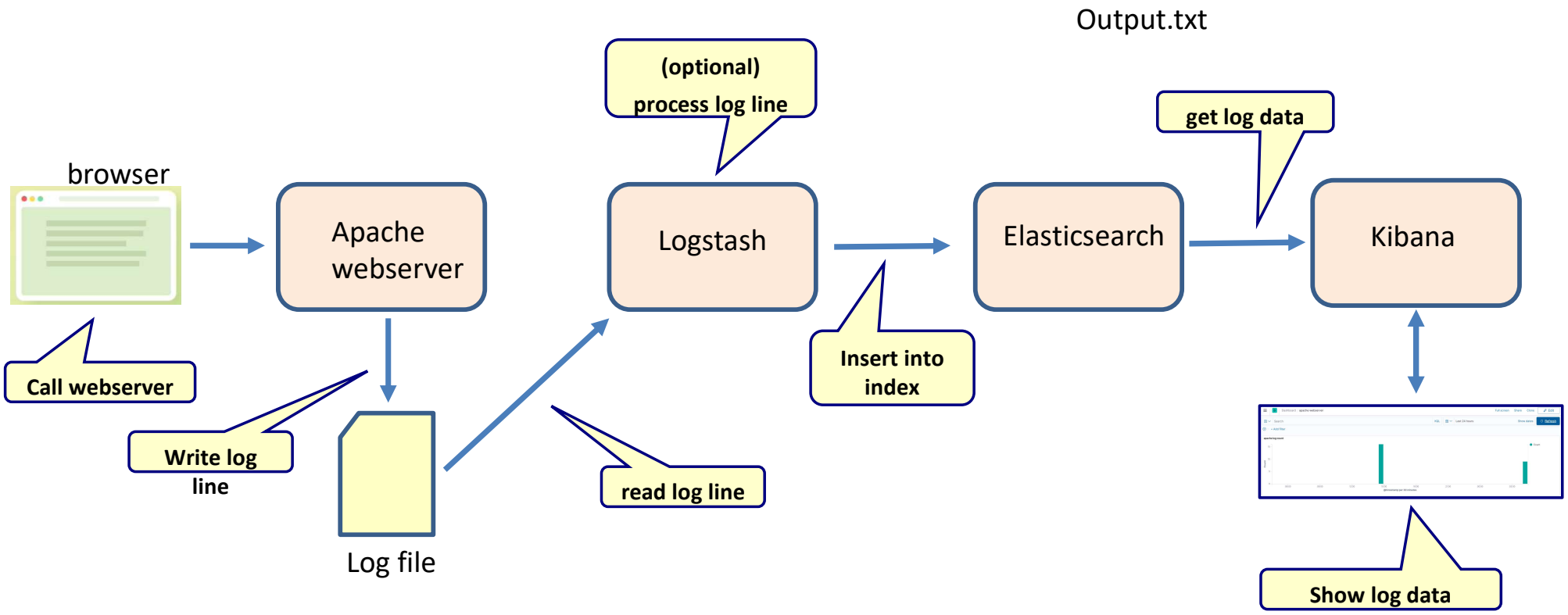
output.txt

```
{
"bytes":"2500",
"@timestamp":"2021-01-16T14:46:40.613Z",
"path":"C:/elasticsearchtraining/temp/input.txt",
"duration":"300",
"method":"GET",
"@version":"1",
"message":"get 2500 300\r",
"host":"DESKTOP-BVHRK6K"
}
```

pipeline.conf

```
input {
  file {
    path => "C:/elasticsearchtraining/temp/input.txt"
    start_position => "beginning"
  }
}

filter {
    grok{
      match => {"message" => "%{WORD:method} %{NUMBER:bytes} %{NUMBER:duration}"}
    }
    mutate {
        uppercase => ["method"]
    }
}

output {
  stdout {
    codec => rubydebug
  }
  file {
    path => "C:/elasticsearchtraining/temp/output.txt"
  }
}
```

logstash example

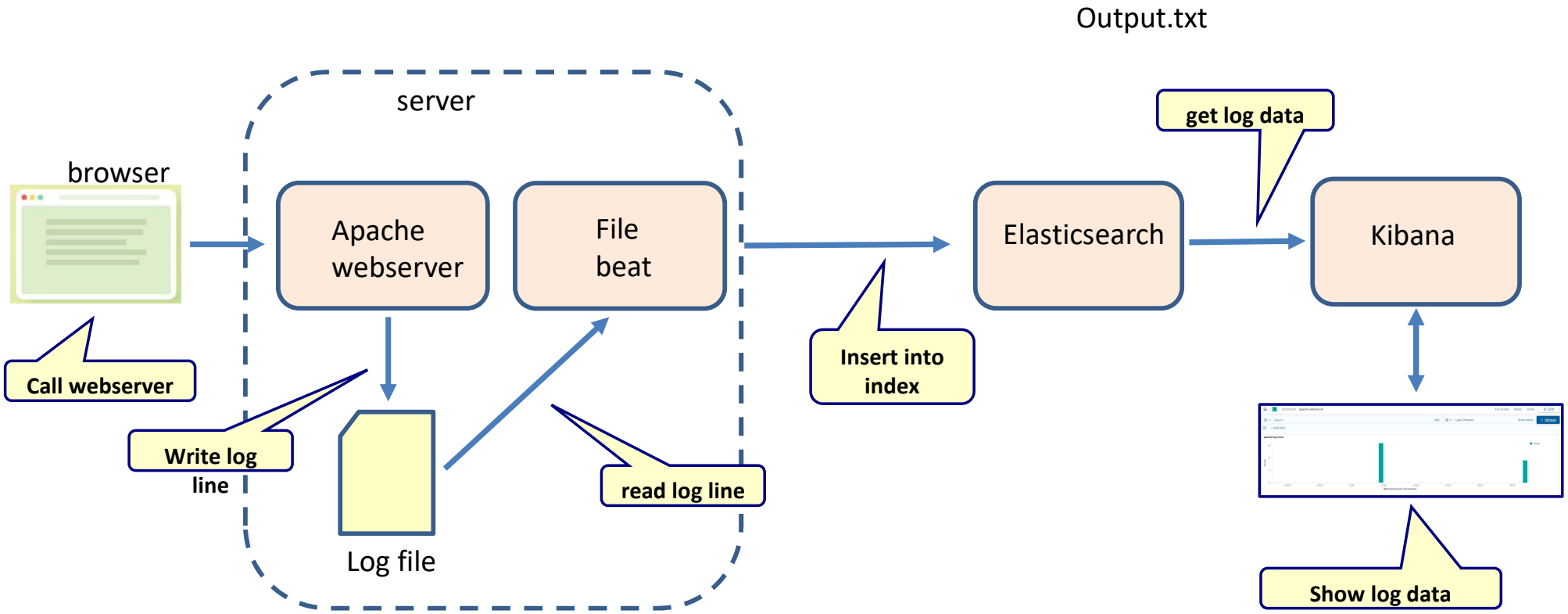


BEATS

Beats

- Data shippers that act as agents installed on the different servers in your infrastructure for collecting logs or metrics
  - log files (Filebeat)
  - network data (Packetbeat)
  - server metrics (Metricbeat)
- Once collected, the data is sent either directly into Elasticsearch or to Logstash for additional processing

filebeat example



Filebeat configuration

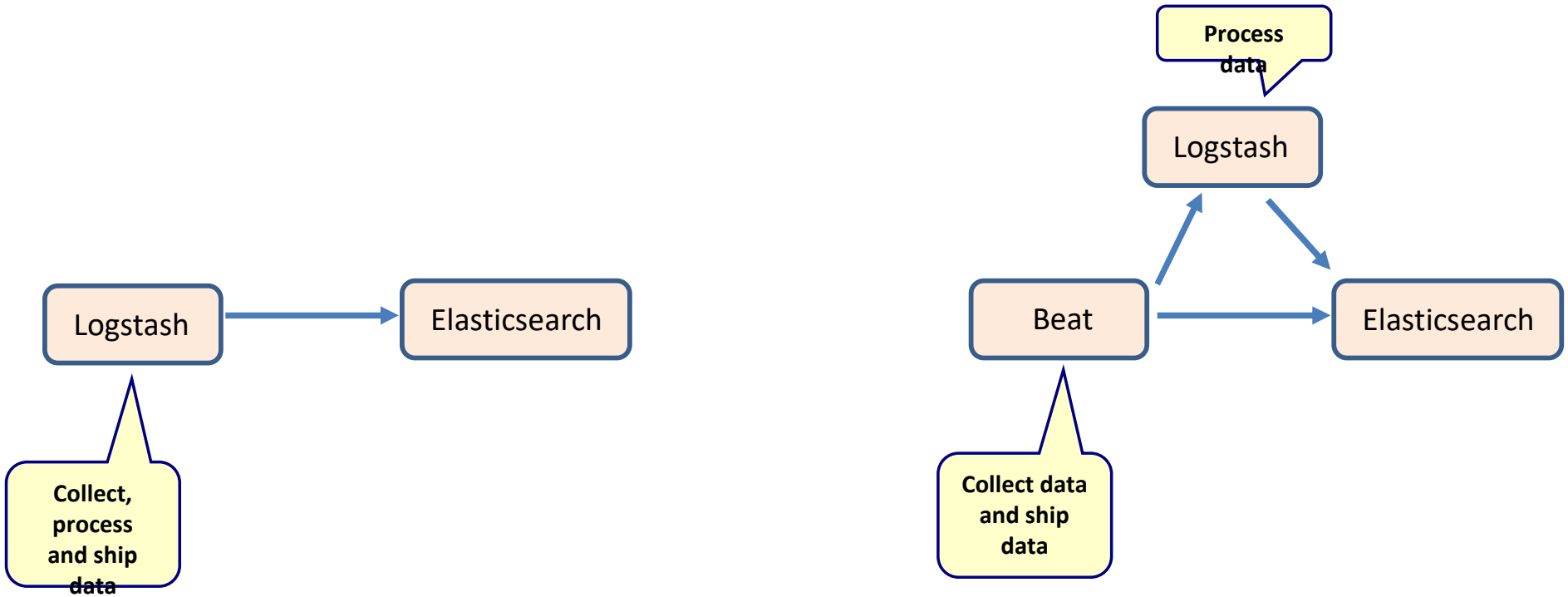
filebeat.yml

```
filebeat.inputs:

# Each - is an input. Most options can be set at the input level, so
# you can use different inputs for various configurations.
# Below are the input specific configurations.

- type: log

  # Change to true to enable this input configuration.
  enabled: true

  # Paths that should be crawled and fetched. Glob based paths.
  paths:
    - C:/elasticsearchtraining/Apache24/logs/access.log


output.elasticsearch:
  # Array of hosts to connect to.
  hosts: ["localhost:9200"]
```

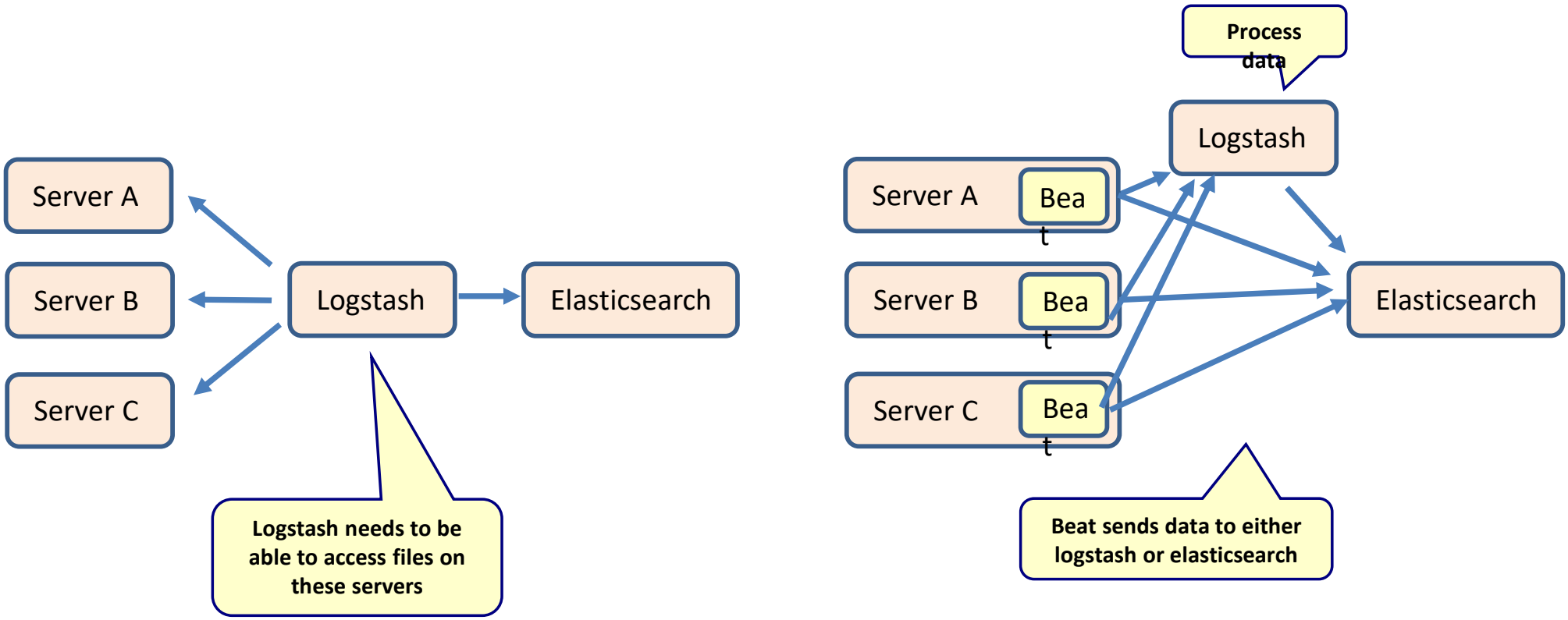
read the access log file

Output to default index 'filebeat' in elasticsearch

Difference between beats and logstash



Difference between beats and logstash



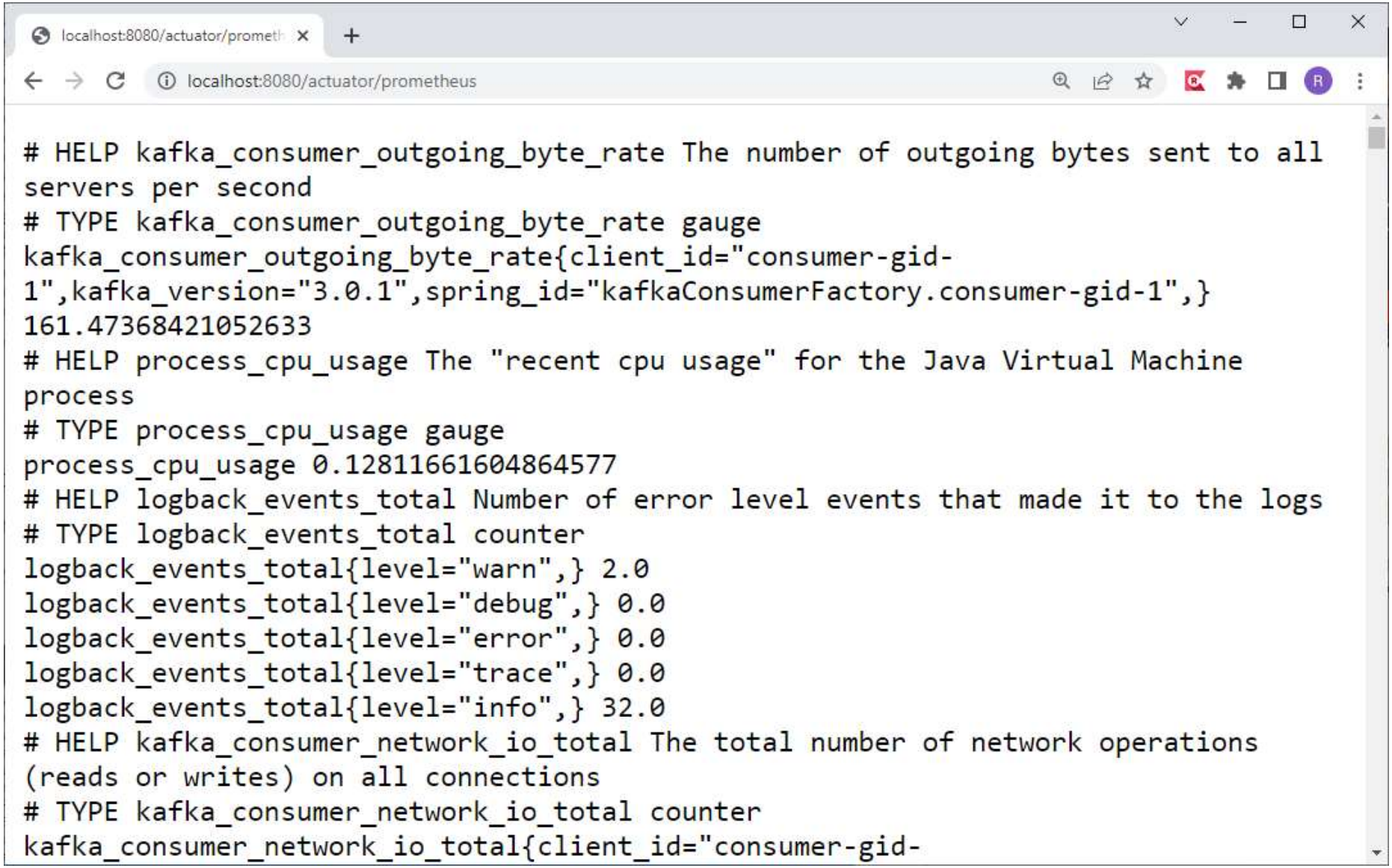
MONITOR ACTUATOR DATA

Micrometer

- Captures metric data and expose this data via an actuator endpoint

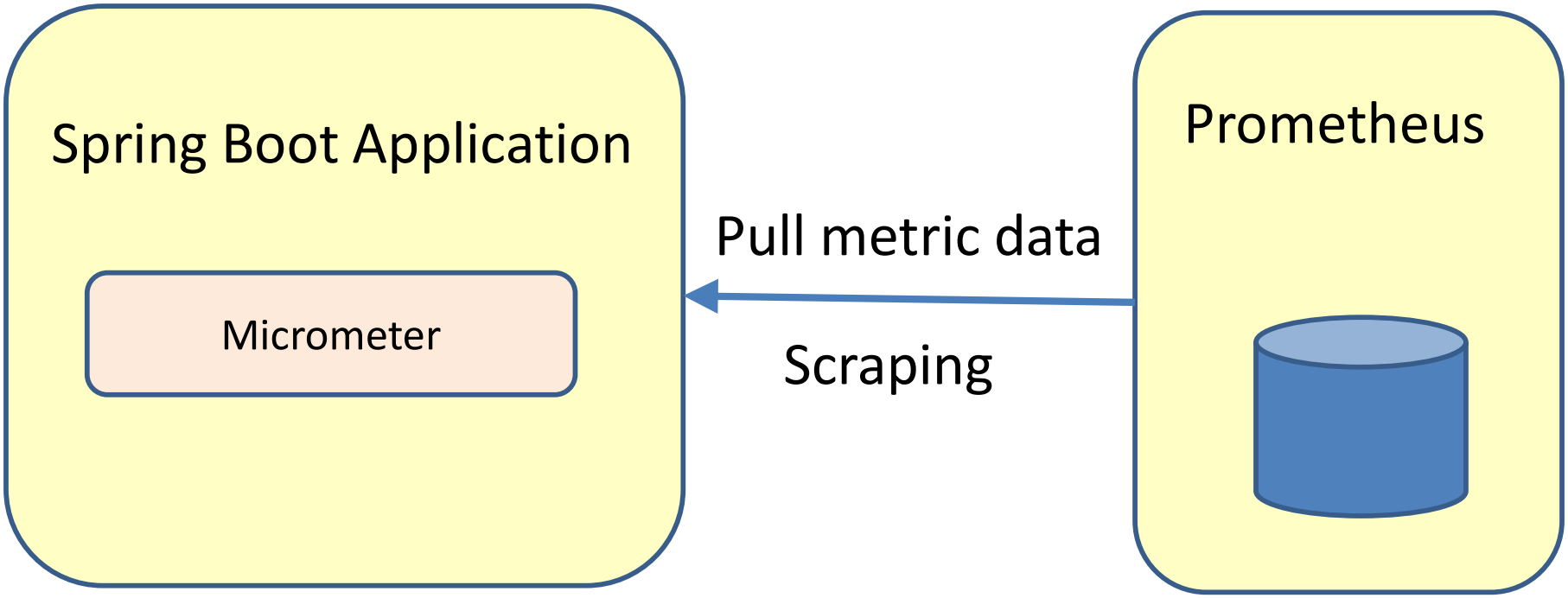
```
<dependency>
  <groupId>io.micrometer</groupId>
  <artifactId>micrometer-registry-prometheus</artifactId>
</dependency>
```

Actuator/prometheus



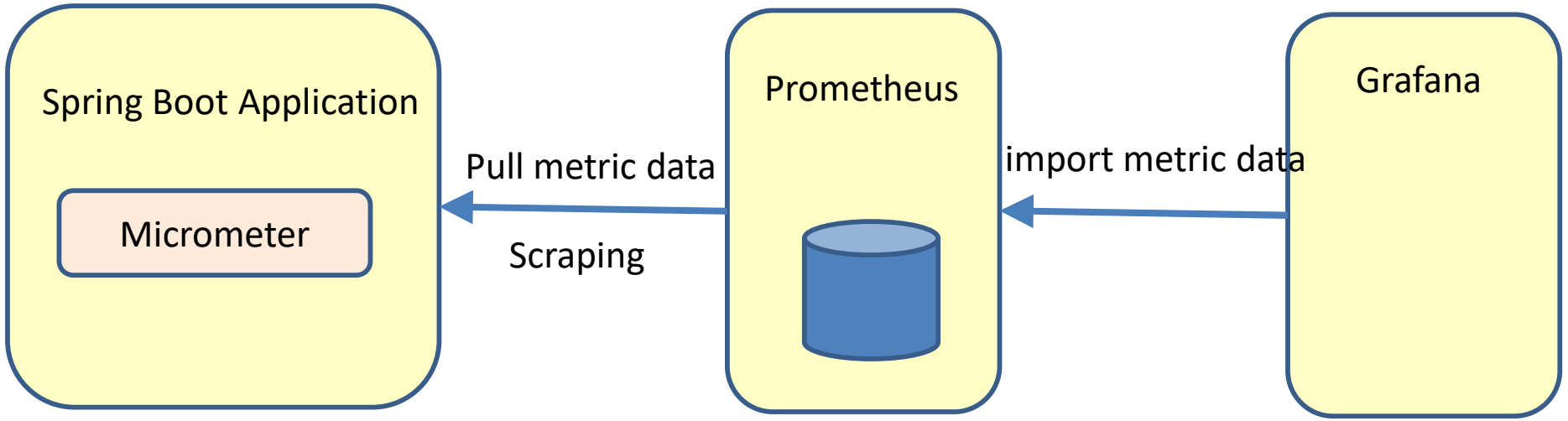
Prometheus

- Time series database
- Stores metric and performance data

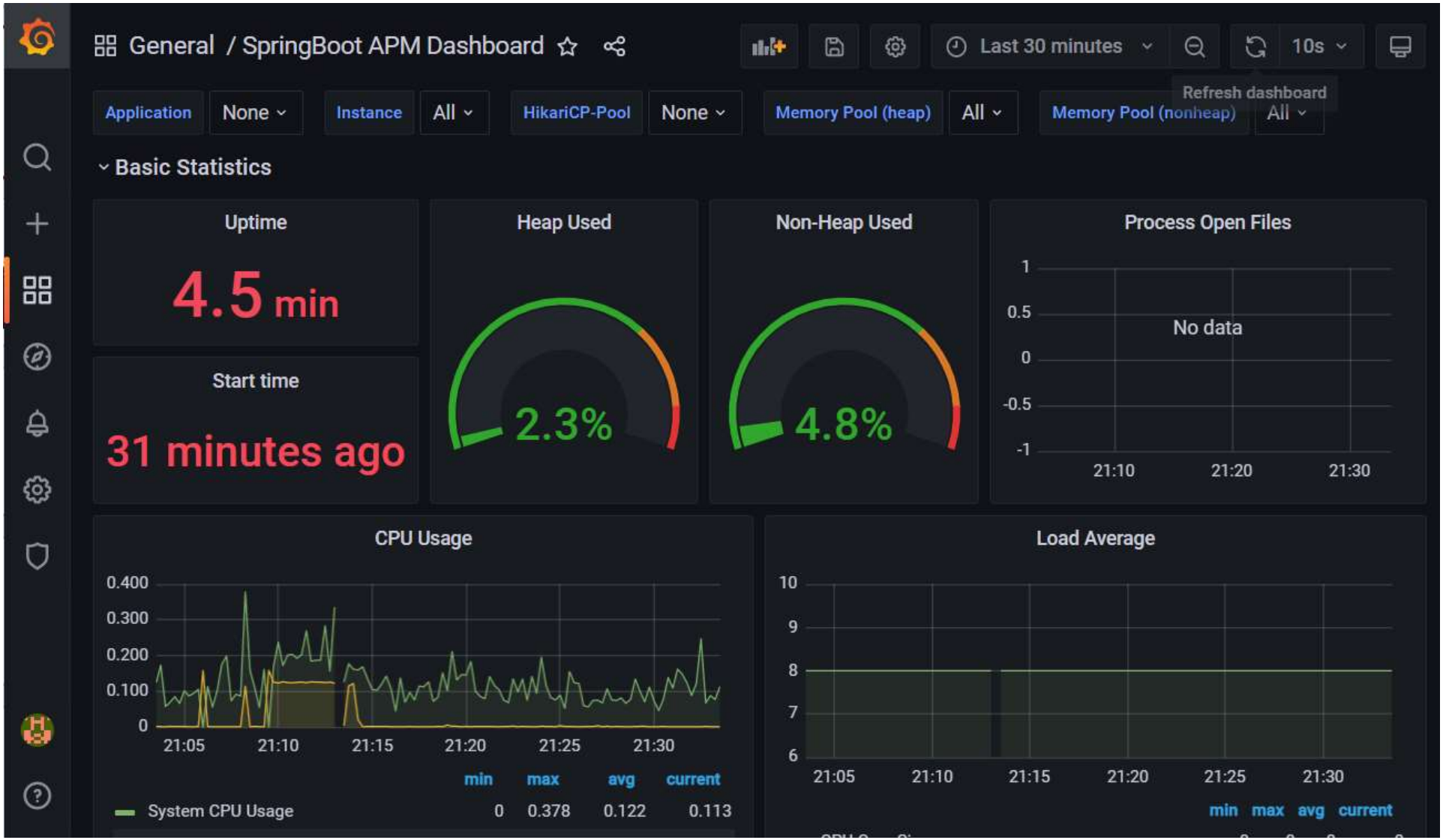


Grafana

- Dashboard to visualize metric data

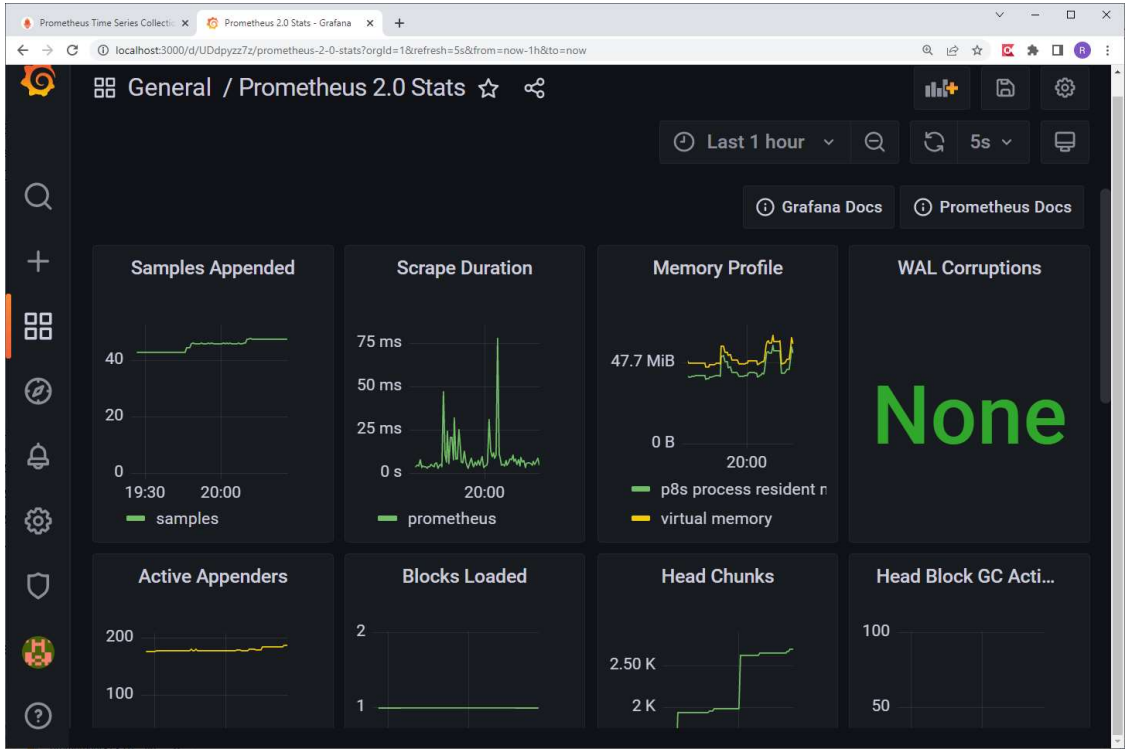


Grafana dashboard



Grafana

- Make your own dashboards
- Alerts
- Refresh interval
- Timespan



UNIT TESTING WITH JUNIT

What is unit testing?

- A unit test is a test that test one single class.
  - A test case test one single method
  - A test class test one single class
  - A test suite is a collection of test classes
- Unit tests make use of a testing framework

- A unit test
  1. Create an object
  2. Call a method
  3. Check if the result is correct

Example of unit testing

```
package count;

public class Counter {
    private int counterValue=0;

    public int increment(){
       return ++counterValue;
    }
    public int decrement(){
       return --counterValue;
    }
    public int getCounterValue() {
       return counterValue;
    }
 }
```

Example of unit testing

```
public class Counter {
    private int counterValue=0;

    public int increment(){
       return ++counterValue;
    }
    public int decrement(){
       return --counterValue;
    }
    public int getCounterValue() {
       return counterValue;
    }
}
```

```
public class CounterTest {
    private Counter counter;

     @BeforeEach
     public void setUp() throws Exception {
       counter = new Counter();
     }
     @Test
     public void testIncrement(){
        assertEquals("Counter.increment does not work correctly",1,counter.increment());
        assertEquals("Counter.increment does not work correctly",2,counter.increment());
     }
     @Test
     public void testDecrement(){
        assertEquals("Counter.decrement does not work correctly",-1,counter.decrement());
        assertEquals("Counter.decrement does not work correctly",-2,counter.decrement());
     }
}
```

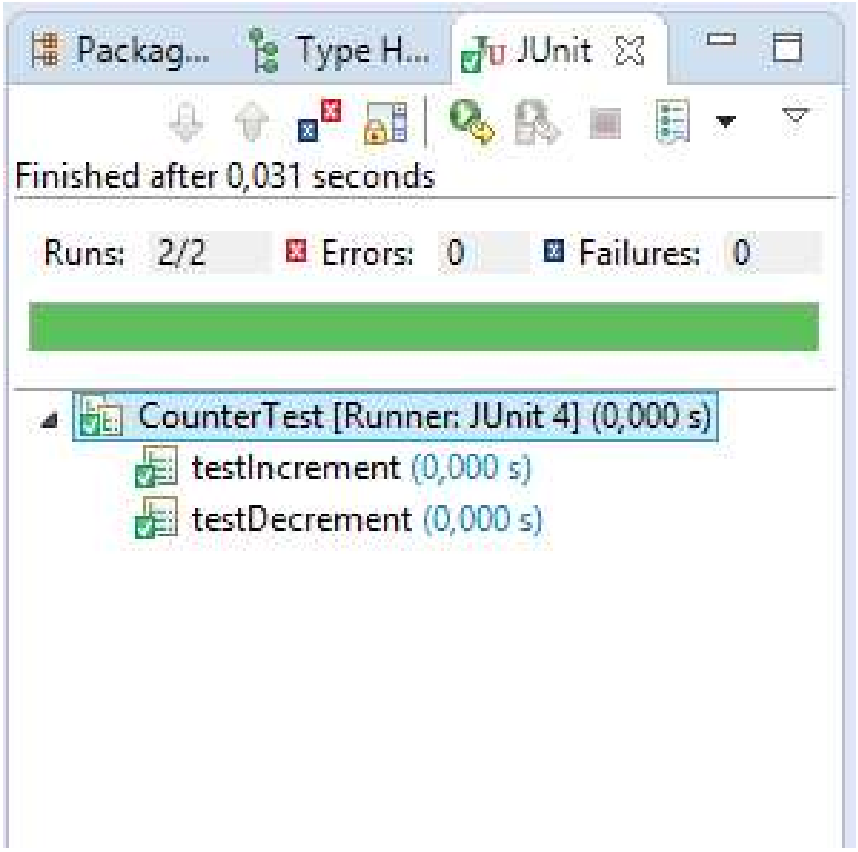
Initialization

Test method

Test method

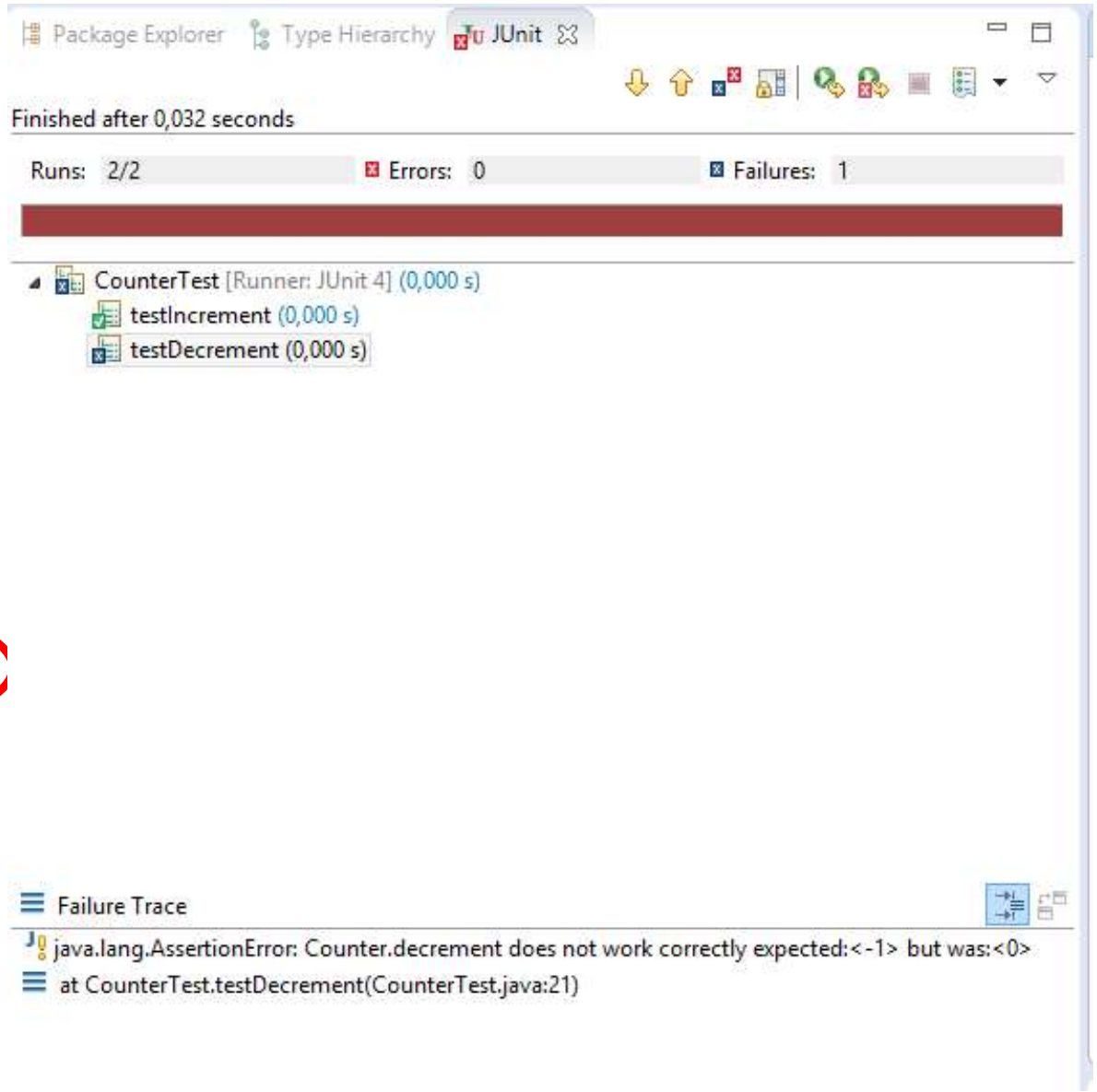
Running the test

```
package count;

public class Counter {
    private int counterValue=0;

    public int increment(){
        return ++counterValue;
    }
    public int decrement(){
        return --counterValue;
    }
    public int getCounterValue() {
        return counterValue;
    }
 }
```



Running the test

```
package count;

public class Counter {
    private int counterValue=0;

    public int increment(){
        return ++counterValue;
    }
    public int decrement(){
        return counterValue;
    }
    public int getCounterValue() {
        return counterValue;
    }
 }
```



JUnit test case

```
public class Calculator
{
    public double add( double number1, double number2 )
    {
        return number1 + number2;
    }
}
```

```
public class CalculatorTest
{
    @Test
    public void add()
    {
        Calculator calculator = new Calculator();
        double result = calculator.add( 10, 50 );
        assertEquals( 60, result, 0 );
    }
}
```

expected

Value to assert

delta

Junit assert methods

- static void assertTrue(boolean ***test***)
- static void assertTrue(String **message**, boolean ***test***)

- static void assertFalse(boolean ***test***)
- static void assertFalse(String **message**, boolean ***test***)

- assertEquals(Object ***expected***, Object ***actual***)
- assertEquals(String **message**, ***expected***, ***actual***)

- assertSame (Object ***expected***, Object ***actual***)
- assertSame(String **message**, Object ***expected***, Object ***actual***)

- assertNotSame(Object ***expected***, Object ***actual***)
- assertNotSame(String **message**, Object ***expected***, Object ***actual***)

- assertNull(Object ***object***)
- assertNull(String **message**, Object ***object***)

- assertNotNull(Object ***object***)
- assertNotNull(String **message**, Object ***object***)

- fail()
- fail(String **message**)

http://junit.org/apidocs/org/junit/Assert.html

@Before and @After

```
public class CounterTest {
    private Counter counter;

    @BeforeEach
    public void setUp() throws Exception {
        counter = new Counter();
    }

    @AfterEach
    public void tearDown() throws Exception {
        counter=null;
    }
    @Test
    public void testConstructor(){
        assertEquals("Counter constructor does not set counter to
                    0",0,counter.getCounterValue());
     }
}
```

This method is called before every testmethod

This method is called after every testmethod

@BeforeClass and @AfterClass

```
public class CounterTest {
    private static Counter counter;

    @BeforeClass
    public static void setUpOnce() throws Exception {
        counter = new Counter();
    }

    @AfterClass
    public static void tearDownOnce() throws Exception {
        counter=null;
    }
    @Test
    public void testConstructor(){
        assertEquals("Counter constructor does not set counter to
                      0",0,counter.getCounterValue());
     }
}
```

This method is called once, before the testmethods are called

This method is called once, after the testmethods are called

Timeout tests

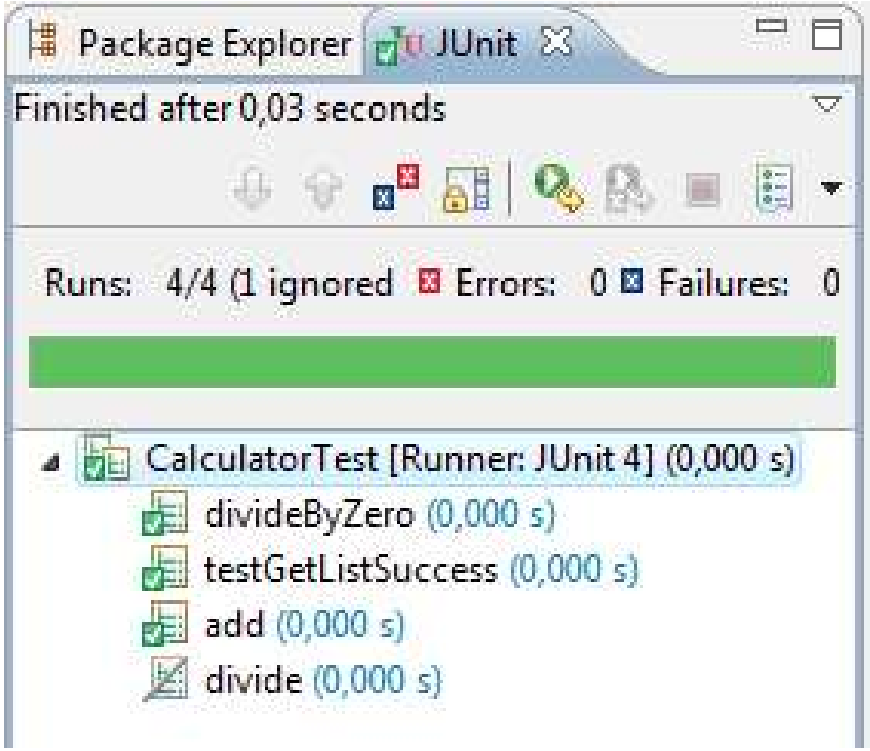
```
@Test(timeout=2000)
public void longOperation() {

}
```

Fail if the test method takes longer than 2000 milliseconds

Skip a test

```
@Test
@Ignore
public void divide(){
    assertEquals( 5, calculator.divide( 10, 2 ), 0 );
}
```

Skip this test



Test suite

```
@RunWith(value=Suite.class)
@SuiteClasses(value={CalculatorTest.class, ParameterizedTest.class})
public class CalculatorTestSuite {

}
```

Suite of 2 test classes

- You can also have a suite of suites
- Organize your tests

JUnit example: Calculator

```
public class Calculator {
    private double value;

    public Calculator() {
      value =0.0;
    }
    public void add(double number) {
      value = value + number;
    }
    public void subtract (double number) {
      value = value - number;
    }
    public void multiply(double number) {
      value = value * number;
    }
    public void divide (double number) throws DivideByZeroException{
      if (number == 0){
        throw new DivideByZeroException();
      }
      value = value / number;
    }
    public double getValue() {
      return value;
    }
}
```

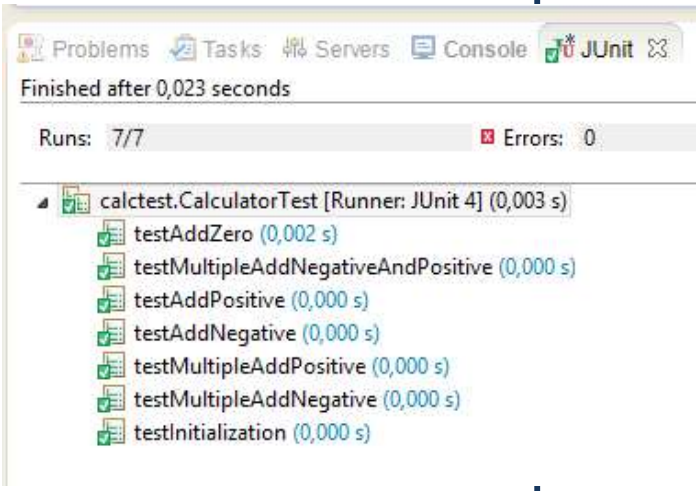
JUnit example: CalculatorTest

```
import calculation.Calculator;

public class CalculatorTest {

  private Calculator calculator;

  @BeforeEach
  public void setup(){
    calculator = new Calculator();
  }

  @Test
  public void testInitialization() {
    assertEquals(0.0, calculator.getValue(),0.0000001);
  }

  @Test
  public void testAddZero() {
    calculator.add(0.0);
    assertEquals(0.0, calculator.getValue(),0.0000001);
  }
```

JUnit example: CalculatorTest

```
@Test
public void testAddPositive() {
  calculator.add(23.255);
  assertEquals(23.255, calculator.getValue(),0.0000001);
}
@Test
public void testAddNegative() {
  calculator.add(-23.255);
  assertEquals(-23.255, calculator.getValue(),0.0000001);
}
@Test
public void testMultipleAddPositive() {
  calculator.add(23.255);
  calculator.add(10.255);
  assertEquals(33.510, calculator.getValue(),0.0000001);
}
@Test
public void testMultipleAddNegative() {
  calculator.add(-23.255);
  calculator.add(-10.255);
  assertEquals(-33.510, calculator.getValue(),0.0000001);
}
@Test
public void testMultipleAddNegativeAndPositive() {
  calculator.add(-23.255);
  calculator.add(10.250);
  assertEquals(-13.005, calculator.getValue(),0.0000001);
}
```

Only test methods for add()



HAMCREST MATCHERS

Traditional asserts

- Parameter order is counter-intuitive
- Assert statements don't read well

assertEquals(***expected***, ***actual***)

```
import static org.junit.Assert.*;

@Test
public void AssertEqualToRed(){
    String color = "red";
    assertEquals("red", color);
}
```

assertThat with hamcrest matchers

```
import static org.junit.Assert.*;
import static org.hamcrest.CoreMatchers.*;
import org.junit.jupiter.api.Before;
import org.junit.jupiter.api.Test;

public class CalculatorHamcrestTest{
Calculator calculator=null;

    @BeforeEach
    public void createAcalculator(){
      calculator = new Calculator();
    }

    @Test
    public void add(){
        assertThat( calculator.add( 10, 50), equalTo (60.0));
    }

    @Test
    public void divide(){
        assertThat(calculator.divide( 10, 2 ), equalTo (5.0));
    }
}
```

Static import of matchers

matcher

assertThat

actual

expected

assert vs assertThat

```
@Test
public void AssertEqualToRed(){
    String color = "red";
    assertEquals("red", color);
}
```

assert

```
@Test
public void hamcrestAssertEqualToRed(){
    String color = "red";
    assertThat(color, equalTo("red"));
}
```

assertThat

assertThat equality tests

```
String color = "red";
assertThat(color, is("red"));
```

assertThat … is

```
String color = "red";
assertThat(color, equalTo("red"));
```

assertThat … equalTo

```
String color = "red";
assertThat(color, not("blue"));
```

assertThat … not

```
String color = "red";
assertThat(color, isOneOf("blue","red"));
```

assertThat … isOneOf

```
List myList = new ArrayList();
assertThat(myList, is(Collection.class));
```

assertThat … is a class

assertThat testing for null values

```
String color = "red";
assertThat(color, is(notNullValue()));
assertNotNull(color);
```

notNullValue

```
String color = null;
assertThat(color, is(nullValue()));
assertNull(color);
```

nullValue

assertThat testing with collections

```
List<String> colors = new ArrayList<String>();
colors.add("red");
colors.add("green");
colors.add("blue");
assertThat(colors, hasItem("blue"));
```

hasItem

```
assertThat(colors, hasItems("red","blue"));
```

hasItems

```
String[] colors = new String[] {"red","green","blue"};
assertThat(colors, hasItemInArray("blue"));
```

hasItemInArray

```
assertThat("red", isIn(colors));
```

isIn

```
List<Integer> ages = new ArrayList<Integer>();
ages.add(20);
ages.add(30);
ages.add(40);
assertThat(ages, not(hasItem(lessThan(18))));
```

Combined matchers

Hamcrest matchers

- Core
  - anything - always matches, useful if you don't care what the object under test is
  - describedAs - decorator to adding custom failure description
  - is - decorator to improve readability
- Logical
  - allOf - matches if all matchers match, short circuits (like Java &&)
  - anyOf - matches if any matchers match, short circuits (like Java ||)
  - not - matches if the wrapped matcher doesn't match and vice versa
- Object
  - equalTo - test object equality using Object.equals
  - hasToString - test Object.toString
  - instanceOf, isCompatibleType - test type
  - notNullValue, nullValue - test for null
  - sameInstance - test object identity
- Beans
  - hasProperty - test JavaBeans properties
- Collections
  - array - test an array's elements against an array of matchers
  - hasEntry, hasKey, hasValue - test a map contains an entry, key or value
  - hasItem, hasItems - test a collection contains elements
  - hasItemInArray - test an array contains an element
- Number
  - closeTo - test floating point values are close to a given value
  - greaterThan, greaterThanOrEqualTo, lessThan, lessThanOrEqualTo - test ordering
- Text
  - equalToIgnoringCase - test string equality ignoring case
  - equalToIgnoringWhiteSpace - test string equality ignoring differences in runs of whitespace
  - containsString, endsWith, startsWith - test string matching