Learning objective: compose futures to avoid blocking as much as possible.

The first 5 exercises are essential.

Exercise 1: future composition prediction
What is the expected output of the following future composition?

```java
System.out.println("Launching computation on " + Thread.currentThread());
CompletableFuture.supplyAsync(() -> {
    System.out.println("Producing 5 on " + Thread.currentThread());
    Thread.sleep(1000);
    return 5;
})
    .thenApply(res -> {
        System.out.println("Adding 2 on " + Thread.currentThread());
        return res + 2;
    })
    .thenCombine(CompletableFuture.supplyAsync(() -> {
        System.out.println("Producing 8 on " + Thread.currentThread());
        return 8;
    }), (res1, res2) -> {
        var res = res1 * res2;
        System.out.println("Multiplying " + res + " on " + Thread.currentThread());
        return res;
    });
System.out.println("Finish launch on " + Thread.currentThread());
```

The order of the last three output lines is not guaranteed.

After 1000 milliseconds:

Adding 2 on thread-1
Multiplying 56 on thread-1

Note that this code is not particularly clear, in particular the fact that the second call to `supplyAsync` is done halfway in the code. We avoid this below.
Exercise 2: composition with sequence and join
Assume variables \( x, y \) and \( z \) are initialized, and functions \( f, g, h \) and \( F \) take some non-negligible amount of time to compute. Propose an asynchronous execution that avoids any blocking operation for the following computation: \( F(g(f(x) + y) + h(z)) \).

There are two independent execution flows (\( f \) and \( g \) for the first and \( h \) for the second) that join before executing the last function, \( F \).

Even though it is possible to merge the processing done with \( \text{thenApply} \), it reduces the number of tasks and may lead to fairness issue (head-of-line blocking). In contrast, too much tasks induces overhead. It is therefore advisable to keep a medium granularity (each task should perform a small but significant amount of work).

```java
CompletableFuture c1 = CompletableFuture.supplyAsync(() -> h(z));
CompletableFuture c2 = CompletableFuture.supplyAsync(() -> f(x))
    .thenApply((res) -> g(res + y))
    .thenCombine(c1, (res1, res2) -> F(res1 + res2));
```

Exercise 3: composition with condition
Similarly, propose an asynchronous execution that avoids any blocking operation for the following computation: first, we compute \( f(x) \); if the result is positive, we compute \( g(f(x)) \), otherwise, \( h(f(x)) \).

```java
CompletableFuture.supplyAsync(() -> f(x))
    .thenApply(res -> res > 0 ? g(res) : h(res))
```

Exercise 4: composition with fork
Similarly, propose an asynchronous execution that avoids any blocking operation for the following computation while minimizing the amount of computation: \( g(f(x)) + h(f(x)) \).

```java
CompletableFuture c1 = CompletableFuture.supplyAsync(() -> f(x));
CompletableFuture c2 = c1.thenApply(res -> h(res));
CompletableFuture c3 = c1.thenApply(res -> g(res));
CompletableFuture c4 = c2.thenCombine(c3, (x, y) -> x + y);
```

Alternatively, we can rely on \( \text{thenCompose} \):

```java
CompletableFuture.supplyAsync(() -> f(x))
    .thenCompose(res -> {
        var cf = CompletableFuture.supplyAsync(() -> g(res));
        return CompletableFuture.supplyAsync(() -> h(res))
            .thenCombine(cf, (x, y) -> x + y)
    })
```

Alternatively, we can write:

```java
var fut1 = new CompletableFuture<Integer>();
var fut2 = new CompletableFuture<Integer>();
```
Exercise 5: rewriting `allOf`
We want to implement the behavior of `allOf` from class `CompletableFuture` that takes multiple completable futures as arguments. From a collection of runnables, build a completable future that represents their completion by relying on `runAfterBoth`.

With streams:

```java
runnables.stream()
    .map(CompletableFuture::supplyAsync)
    .reduce((c1, c2) -> c1.runAfterBoth(c2, () -> {}))
    .get()
```

With loops:

```java
CompletableFuture<Void> fut = null;
for (Runnable runnable : runnables)
    if (fut == null)
        fut = CompletableFuture.supplyAsync(runnable)
    else
        fut = fut.runAfterBoth(CompletableFuture.supplyAsync(runnable), () -> {})
```

Exercise 6: rewriting `anyOf`

Same question with `anyOf` and `runAfterEither`.

With streams:

```java
runnables.stream()
    .map(CompletableFuture::supplyAsync)
    .reduce((c1, c2) -> c1.runAfterEither(c2, () -> {}))
    .get()
```

With loops:

```java
CompletableFuture<Void> fut = null;
for (Runnable runnable : runnables)
    if (fut == null)
        fut = CompletableFuture.supplyAsync(runnable)
    else
        fut = fut.runAfterEither(CompletableFuture.supplyAsync(runnable), () -> {})
```