Advanced Generics

Jesper de Jong

Software Architect

@jesperdj | www.jesperdj.com

This Module

Generic types

Type parameters
Parameterized types
Type arguments

Generic methods

Bounded type parameters

Raw types

Generics and inheritance

Wildcards

Unbounded
Upper bounded
Lower bounded

Type erasure

Generics and arrays

Explanation: Defining Generic Types

Type parameter

```
public class LeafNode<T> implements TreeNode<T> {
    // implementation here
}
```

Generic Types

Type parameters and type arguments

```java
public class LeafNode<T> implements TreeNode<T> {
    // implementation here
}

var three = new LeafNode<Integer>(3);
```

Type argument

Generic Types

Type parameters and type arguments

```
public class LeafNode<T> implements TreeNode<T> {
    // implementation here
}

var three = new LeafNode<Integer>(3);
```

Generic Types

Instantiating a generic type into a parameterized type

```
public class LeafNode<T> implements TreeNode<T> {
    // implementation here
}

var three = new LeafNode<Integer>(3);
```

Generic Types

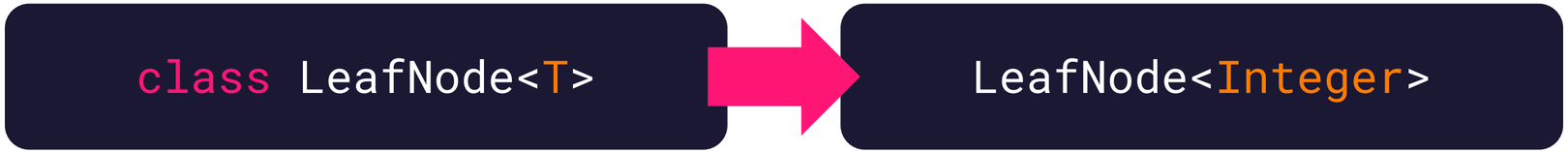
Creating an instance (object) of a parameterized type

Value Level and Type Level

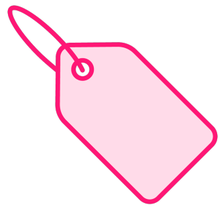
Define methods and constructors with value parameters (int a, String b)	Define generic types with type parameters <K, V>
Call methods and constructors with arguments - actual values (123, “Hello”)	Supply type arguments – actual types for the type parameters <Integer, String>
Instantiate a type into an object	Instantiate a generic type into a parameterized type

Terminology

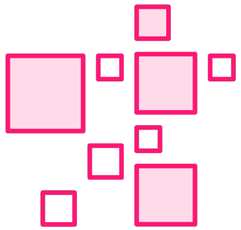
A generic type is a type with type parameters, which is instantiated into a parameterized type by supplying type arguments to fill in its type parameters.



More About Generic Types



Single capital letter names for type parameters are a widely accepted convention



You cannot use primitive types as type arguments

Anonymous inner classes, enums and exception classes cannot have type parameters

Use Cases for Generic Types

Generic data structures

Code reuse

Generic abstract superclass

Use Cases for Generic Types

```
abstract class Screen<T> {}

class BusinessContractScreen
    extends Screen<BusinessContractOptions> {}

class PersonalContractScreen
    extends Screen<PersonalContractOptions> {}
```

Raw Types

Raw Types

```
List objects = new ArrayList(); // No type arguments <...>
```

Raw Types

```
List objects = new ArrayList(); // No type arguments <...>

objects.add("Hello");
objects.add(123);
```

Raw Types

```
List objects = new ArrayList(); // No type arguments <...>

objects.add("Hello");
objects.add(123);

String text = (String) objects.get(1); // ClassCastException
```

Avoid using raw types.

They only exist for backward compatibility.

Wildcards

What is a Wildcard?

A wildcard is a way to refer to a family of types

```
?
```

Unbounded wildcard

```
? extends SomeType
```

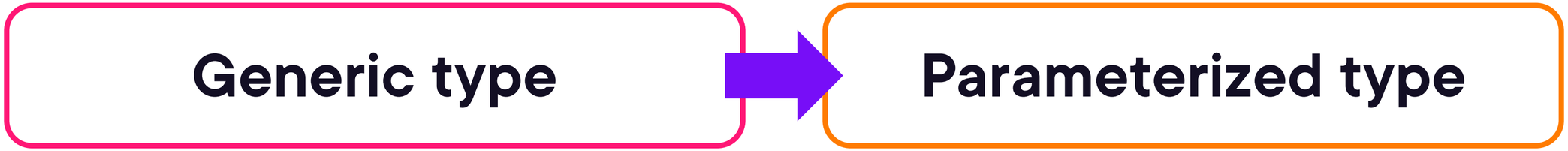
Upper bounded wildcard

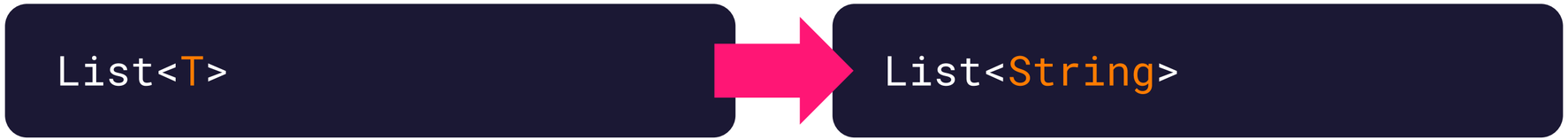
```
? super SomeType
```

Lower bounded wildcard

Used to declare wildcard parameterized types

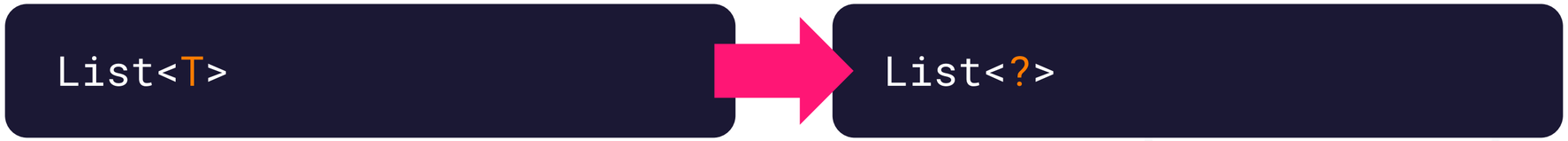
Wildcard Parameterized Types





Generic type

Concrete parameterized type



Generic type

Wildcard parameterized type

Wildcard Parameterized Types

```
List<String>
```

Concrete parameterized type

```
List<?>
```

Wildcard parameterized type

A single, fully defined type

Not a single type

Matches a family of types

Matching Wildcard Parameterized Types

Using Wildcards in Practice

Using Wildcards in Practice

Defining methods that take parameters of parameterized types

Avoid unnecessary restrictions

Example: Collections.copy()

```
public static <T> void copy(List<? super T> dest, List<? extends T> src)
```

Example: Collections.copy()

```
public static <T> void copy(List<T> dest, List<T> src)
```

Requires dest and src to have the exact same element type

```
List<Dog> dogs = List.of(new Dog("Daisy"), new Dog("Lucky"));
List<Animal> animals = new ArrayList<>();
```

Example: Collections.copy()

```
public static <T> void copy(List<T> dest, List<T> src)
```

Requires dest and src to have the exact same element type

```
List<Dog> dogs = List.of(new Dog("Daisy"), new Dog("Lucky"));
List<Animal> animals = new ArrayList<>();
copy(animals, dogs);
```

Example: Collections.copy()

```
public static <T> void copy(List<T> dest, List<T> src)
```

Requires dest and src to have the exact same element type

```
List<Dog> dogs = List.of(new Dog("Daisy"), new Dog("Lucky"));
List<Animal> animals = new ArrayList<>();
copy(animals, dogs); // Error: Type mismatch
```

Example: Collections.copy()

```
public static <T> void copy(List<? super T> dest, List<? extends T> src)
```

```
List<Dog> dogs = List.of(new Dog("Daisy"), new Dog("Lucky"));
List<Animal> animals = new ArrayList<>();
copy(animals, dogs); // OK
```

Example: Collections.copy()

```
public static <T> void copy(List<? super T> dest, List<? extends T> src)
```

Upper bounded wildcards for in parameters

Lower bounded wildcards for out parameters

No wildcard for a parameter that is both in and out

Unbounded Wildcard Parameters

```
public static int size(List<?> list)
```

Unbounded wildcard if the method does not need to know what the wildcard stands for

Example: Stream.flatMap()

```
<R> Stream<R> flatMap(Function<? super T, ? extends Stream<? extends R>> mapper)
```

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```
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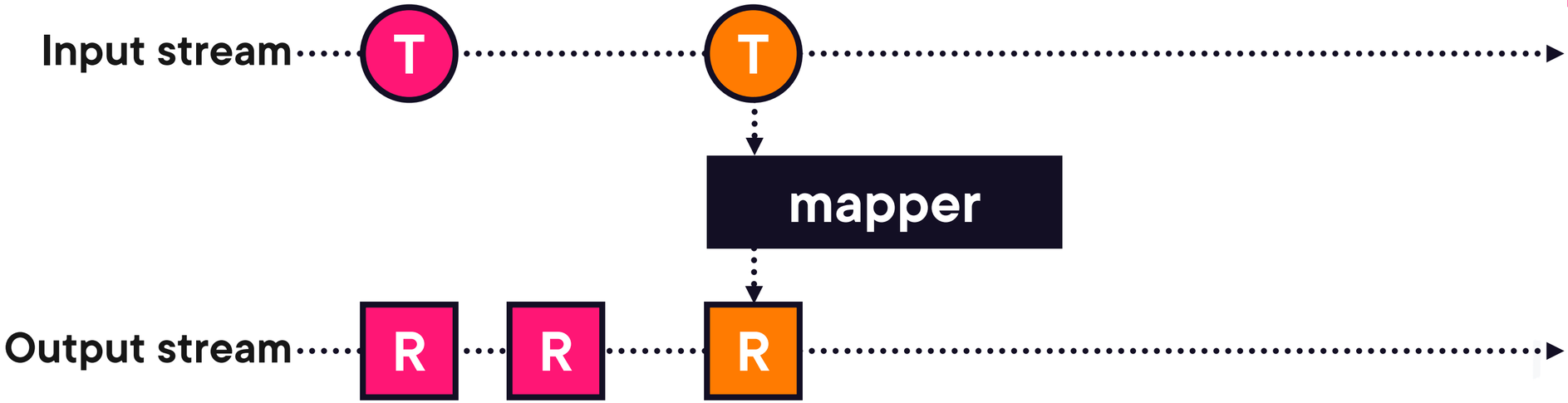
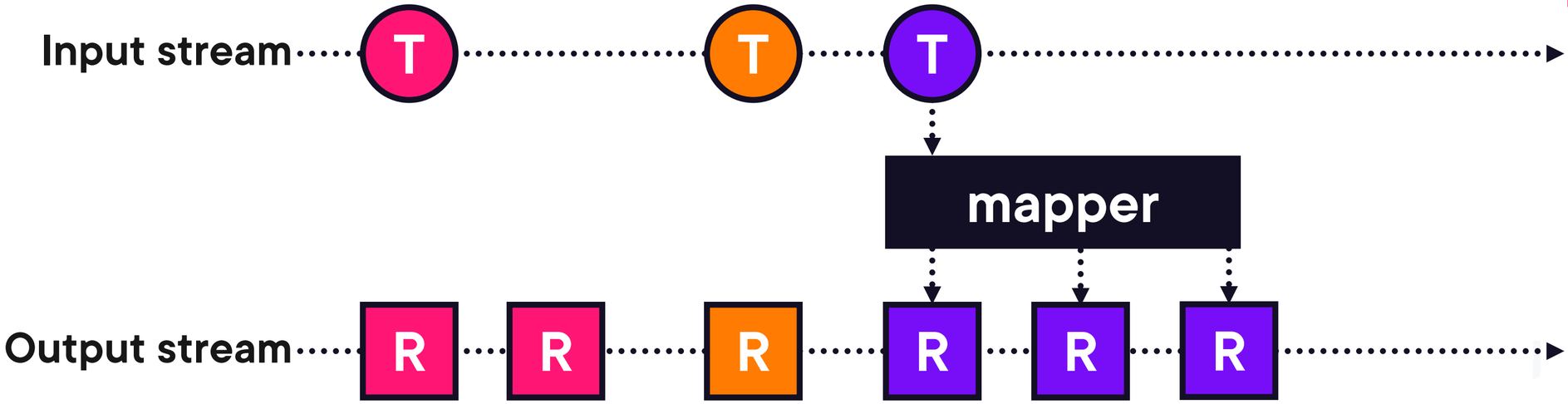


Example: Stream.flatMap()

```
<R> Stream<R> flatMap(Function<? super T, ? extends Stream<? extends R>> mapper)
```



One-to-many transformation of a stream of T into a stream of R

Example: Stream.flatMap()

```
<R> Stream<R> flatMap(Function<? super T, ? extends Stream<? extends R>> mapper)
```

A function that takes an ? super T
and returns an ? extends Stream<? extends R>

T – Type of the elements of the Stream that flatMap is called on

R – Type of the elements of the Stream that flatMap returns

Example: Stream.flatMap()

```
<R> Stream<R> flatMap(Function<? super T, ? extends Stream<? extends R>> mapper)
```

A function that takes an ? super T
and returns an ? extends Stream<? extends R>

Upper bounded wildcards for in parameters

Lower bounded wildcards for out parameters

Example: Stream.flatMap()

```
<R> Stream<R> flatMap(Function<? super T, ? extends Stream<? extends R>> mapper)
```

Avoid using wildcards in the return type of a method

Practice Reading Wildcard Method Signatures

```
class java.util.Collections
```

```
interface java.util.Comparator
```

```
interface java.util.stream.Stream
```

```
class java.util.stream.Collectors
```

Type Erasure

Type Erasure

Generics are a compile-time only feature

Generic and parameterized types,
type parameters and type arguments do not exist at runtime

Type parameters are replaced by Object or the leftmost bound

Type arguments are discarded

Parameterized types are replaced by raw types

Type casts are added where necessary

Limitations Caused by Type Erasure

Limitations Caused by Type Erasure

You cannot use primitive types as type arguments

Because primitive types are not objects

Limitations Caused by Type Erasure

It’s not possible to create
a new instance of a type parameter

```
new T(); // Error
```

```
Class<T> cls = ...;
var obj = cls.getDeclaredConstructor().newInstance();
```

Limitations Caused by Type Erasure

instanceof does not work with non-reifiable types

Non-reifiable type — **A type for which type information is lost during type erasure**

Parameterized types with at least one concrete or bounded wildcard type argument

```
obj instanceof List<String> // Error
```

Limitations Caused by Type Erasure

instanceof does not work with non-reifiable types

Non-reifiable type — **A type for which type information is lost during type erasure**

Parameterized types with at least one concrete or bounded wildcard type argument

```
obj instanceof List<?> // OK
```

Limitations Caused by Type Erasure

No class literals for parameterized types

```
Class<?> cls = List<String>.class // Error
```

Limitations Caused by Type Erasure

Operations where type safety cannot be guaranteed cause unchecked warnings

Limitations Caused by Type Erasure

You cannot overload methods
with the same method signature after type erasure

```
void print(List<String> strings)

void print(List<Integer> integers)
```

Limitations Caused by Type Erasure

You cannot overload methods
with the same method signature after type erasure

```
void print(List strings)

void print(List integers)
```

After type erasure

Heap Pollution

Separately compiled source files

PetStore.java

```
public List<Dog> getPets() {
    return List.of(
        new Dog("Daisy"),
        new Dog("Lucky"));
}
```

Application.java

```
List<Dog> pets = petStore.getPets();
```

Heap Pollution

Separately compiled source files

PetStore.java

```
public List<Dog> getPets() {
    return List.of(
        new Dog("Daisy"),
        new Dog("Lucky"));
}
```

Application.java

```
List<Cat> pets = petStore.getPets();
```

Summary

Defining generic types and methods

- Generic types and type parameters
- Parameterized types and type arguments

Bounded type parameters

Raw types

Generics and inheritance

- Generic types are invariant

Summary

Wildcards

- Wildcard parameterized types
- Unbounded: ?
- Upper bounded: ? extends Type
- Lower bounded: ? super Type

Type erasure

Heap pollution

Generics and arrays

Generics and varargs

Value Level and Type Level

Define methods and constructors with value parameters (int a, String b)	Define generic types with type parameters <K, V>
Call methods and constructors with arguments - actual values (123, “Hello”)	Supply type arguments – actual types for the type parameters <Integer, String>
Instantiate a type into an object	Instantiate a generic type into a parameterized type

A wildcard stands for a specific, but unknown type

```
List<?>
```

A list of objects of a specific unknown type

You cannot add elements to this list because the type is unknown

Up Next:

Lambda Expressions and Method References