Types

S is a *subtype* of T (`S <: T`) if a piece of code written for S can be used for variables of T

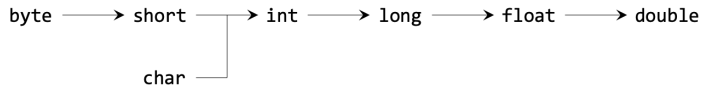
1. **Reflexive** - $S <: S$
2. **Transitive** - if $S <: T$ and $T <: U$, then $S <: U$
3. **Anti-symmetry** - if $S <: T$ and $T <: S$, then $S = T$

`S instanceof T` returns true if $S <: T$

Type Conversions

Narrowing	Widening
$S <: T$, we can type cast a variable of type T to type S	$S <: T$, we can type cast a variable of type S to type T
`Circle c=(Circle) new Shape()` *requires **explicit typecasting** and **validation** at runtime	`Shape s = new Circle()`

Primitive Types



Variance of Types

$C(S)$ stands for complex types - arrays
Covariant - $S <: T$ implies $C(S) <: C(T)$
Contravariant - $S <: T$ implies $C(T) <: C(S)$
Invariant - neither *covariant* nor *contravariant*

* Java **array** is *covariant*
* Java **generics** are *invariant*
* Java arrays and generics **cannot be mixed**

Run-time VS Compile-Time

`Circle c = new ColouredCirlce(...)`
Compile-time type - `Circle`
Run-time type - `ColouredCircle`

OOP Principles

Encapsulation

Hides internal representation and implementation
Exposes just the required method interface for use

Noun	Properties	Associated Verbs
Class	Fields	Methods

Composition - *HAS-A* relationship

Inheritance

`extends` *IS-A* relationship

Polymorphism

Using same method signatures in different subclasses to determine which method should be executed

Dynamic Binding
1. Determine compile-time type of target
2. Look for all available methods
3. Choose the most specific method
4. Determine run-time type of target

Method Signatures and Descriptors

Method Signature - method name, number of parameters, type of each parameter, order of parameters
`C::foo(B1, B2)`

Method Descriptor - method signature + return type
`A C::foo(B1, B2)`

Method Overriding and Overloading

Overriding - Same method signature
Overloading - Same method name, but different method signatures

Information Hiding (Abstraction)

`private` fields, `public` methods

Tell-Don't-Ask

Should get the class to perform a task instead of retrieving the *internal* values and performing the task ourselves

Liskov Substitution Principle

If $S <: T$:

- S should be able to pass all test cases of T
- S should not break any expectations and expected attributes of T - i.e. S should contain all fields and methods of T
- S should be able to replace T and not break any logic

Violation of LSP - if S does not fulfill any of the above conditions

Preventing Inheritance (classes) and Overriding (methods) - `final`

Abstract Classes

`abstract class A {}`
used when one or more of its instance methods require further details to implement

Concrete class
A class that is not abstract - overrides any `abstract` methods in its parent class

Interfaces

`interface GetAreable {}`
Models what an entity can do

`class A implements X, Y, Z`
Classes can implement multiple interfaces
If `class A implements X`, $A <: X$

`interface X extends Y, Z`
Interfaces can extend multiple interfaces, but cannot extend (abstract!)

Wrapper Class

Primitive	Wrapper
int	Integer
double	Double
char	Character
boolean	Boolean

Enables flexible programs at the cost of performance since primitive wrapper class objects are **immutable**
Leads to overhead for memory allocation and garbage collection

Auto-(un)boxing

```
Integer i = 4
// auto-boxing: int 4 converted to an instance of Integer
int j = i
// auto-unboxing: converts instance of Integer back to int
```

Exceptions

```
class NewCheckedExceptions extends Exception {
        public NewCheckedExceptions() {
                super("message")
        }
}
class NewUncheckedExceptions extends RunTimeException

class C throws NewCheckedException {
        throw new NewCheckedException("message")
}
...
try {
    // do something
} catch (NewCheckedException e | exception 2) {
        System.out.println(e.getMessage());
    // handle exception 2
} finally {
    // runs regardless of exception occurrence
}
```

Generics

Allow classes/methods to be defined without using `Object` type

- Enforces **type safety** → binds a generic type to specific type at compile type
- errors will be at *compile time* instead of run-time time

```
class Pair<S, T> {...]

// DictEntry follows the T type in Pair
class DictEntry<T> extends Pair<String, T> {...}

// bounded parameters
class Pair<S extends Comparable<S>, T> {...}

// arrays and generics dont mix
// need to declare before assigning
class Seq<T> {
```

```
  private T[] array;

  public Seq(int size) {
    // The only way we can put an object into array
    // is through the method set() and we only put
    // object of type T inside. So it is safe to
    // cast `Object[]` to `T[]`.
    @SuppressWarnings("unchecked")
    T[] a = (T[]) new Object[size];
    this.array = a;
  }
}
```

Generic Methods

```
// type parameter must appear before the return type
public static <T> boolean contains(T[] arr, T obj) {}

// to call a generic method
A.<Circle>contains(...)

// bounded class generics method
public static <T extends GetAreable> T
    findLargest(T[] arr)

// instance method
public <U> void printSomething(U value)
```

Notes

```
B implements Comparable<B> {...}
A extends B {...}
A <: B <: Comparable<B> <: Comparable<?>
Comparable<A> INVARIANT Comparable<B>
Comparable<A> <: Comparable<? extends B>
```

Type Erasure

During compilation, type parameters are erased and replaced with the most specific reference type
* `Object` for unbounded and the **bound** for bounded parameters

Heap pollution - situation where a parameterized type expects to hold an object of type X but stores an object of type Y instead

Suppress warnings

- only suppress warnings if it causes a type error
- `@SuppressWarnings` can only be applied to declarations and not assignments

Raw Types

A generic type used without type arguments
Only use together with `instanceof` - `a instanceof A`
Wildcards eliminate this need since we can now do "`a instanceof A<?>`"
`Seq<?>` - sequence of specific, but unknown types
`Seq` - sequence of Object instances, no type checking
`Seq<Object>` - sequence of Object instances

Wildcards

PECS - Producer *Extends*, Consumer *Super*

Upper-bounded - `V<? extends A>`

When we want to **retrieve from** instead of adding to

- Covariance
- if `S <: T`, then `A<? extends S> <: A<? extends T>`
- `A<S> <: A<? extends S>`

```
public void copyFrom(Seq<? extends T> src) {
    int len = Math.min(this.array.length,
        src.array.length);
    for (int i = 0; i < len; i++) {
        this.set(i, src.get(i));
    }
}
```

Lower-bounded - `V<? super A>`

When we want to **add to** a collection instead of retrieving from

- Contravariance
- if `S <: T`, then `A<? super T> <: A<? super S>`
- `A<S> <: A<? super S>`

```
public void copyTo(Seq<? super T> dest) {
    int len = Math.min(this.array.length,
        dest.array.length);
    for (int i = 0; i < len; i++) {
        dest.set(i, this.get(i));
    }
}
```

Unbounded - `V<?>`

The parent class of all wildcards
* `Array<?>` is the supertype of all `Array<T>`

Type Inference

Ensures **type safety** - compiler can ensure that `List<myObj>` holds objects of type `myObj` at *compile time* instead of *run time*
* `<? super Integer>` - inferred as `Object`
* `<? extends Integer>` - inferred as `Integer`

Diamond Operator
`Pair<String,Integer> p = new Pair<>();`
p would be inferred as an instance of `Pair<String,Integer>`

Constraints
1. Target typing - the return expression (i.e. `Shape o = statement()`)
2. Type parameter bound - `public static <T extends GetAreable>`
3. Argument parsed - `Seq<Circle> <: Seq<? extends T>`, so `T <: Circle`

```
public static <T extends GetAreable> T
    findLargest(Seq<? extends T> seq) {...}
Shape o = A.findLargest(new Seq<Circle>(0));
```

Most specific
`Type1 <: T <: Type2 - T = Type1`
`Type1 <: T - T = Type1`
`T <: Type2 - T = Type2`

Java

Access modifiers

- `public`/`private` - fields accessible/inaccessible from outside the class
- `static` - associate field with class
- `final` - value will not change

`this` - refers to current instance