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Exercise 8

Parametric polymorphism

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Task 1

Consider the following Scala classes:

```
class A
class B extends A
class P1[+T]
class P2[T <: A]
```

What are the possible instantiations of `P1` and `P2`? What is the difference between `P1[A]` and `P2[A]` from the perspective of a client? Provide an example to show which class is more restrictive.

Task 2

Implement a list in Java or C# with two methods:

```
public void add(int i, Object el)
public Object get(int i)
```

Implement the list and discuss the advantages and the limitations of the three different approaches below.

A) Implement the list using only one class without generics.

B) Implement the list using one abstract class/interface and then (some) subclasses that implement it for different types.

C) Implement the list using generic types.

Task 3 Wildcards *(from a previous exam)*

Consider the following Java code:

```
class Car<T> {
    private List<? extends T> passengers;

    public Car(List<? extends T> passengers) {
        this.passengers = passengers;
    }
}
```

Remember that `List<E>` in Java contains a method `addAll` with the following signature:

```
boolean addAll(Collection<? extends E> c)
```

Method `addAll` adds all elements of the given collection `c` to the receiver list and returns `true` if the receiver list was modified.

A) We want to add a method to `Car<T>` that takes a list of passengers `p` to board the car. After the method is executed, the field `passengers` should refer to a list containing both the previous elements and the elements of `p`.

```
public void board(List<? extends T> p)
```

The following implementation is rejected by the compiler:

```
public void board(List<? extends T> p) {
    this.passengers.addAll(p);
}
```

Assume the body of `board` is exempted from the type checker. Provide code that calls `board` and inserts a string into a list of integers. Your code has to type-check.

B) Give a new implementation of `board` (without modifying its signature) that implements the expected functionality and type-checks.

C) We now want to add a method to class `Car<T>` that transfers all passengers from this car to a given car. Fill in the blank to achieve the least restrictive but correct implementation.

```
public void transferPassengers(Car<__________> other) {
    other.board(this.passengers);
}
```

Task 4

Consider the following Java method:

```
String concatenate(List<?> list) {
   String  result="";
   String separator="";
   if(list instanceof List<String>) {
      result="String:";
      separator=" ";
   }
   else if(list instanceof List<Integer>) {
      result="Integers:";
      separator="+";
   }
   for(Object el : list)
      result=result+separator+el.toString();
   return result;
}
```

A) This program is rejected by the Java compiler. Why?

B) Using the advice given by the Eclipse Java compiler (replace `List<...>` with `List<?>`), rewrite and compile the program. What are the results of executing the method passing each of the following:

- A list of strings containing only one element "word"?
- A list of Integers containing only one element Integer(1)?
- A list of Objects containing only one element (initialized by new Object())?

C) Is this behaviour consistent with what you would expect from the initial program? If not, how can you fix it?

D) What would happen if you tried to implement the different cases using method overloading instead of just one method. Why is this the case?

E) What happens if you compile and execute the initial program in C# ? Why?

Assume that we replace the wildcard by a method type parameter `T` to make it work in C#.

Task 5

Consider the following Java method:

```
public void add(Object value, List<?> list) {
   list.add(value);
}
```

The Java compiler rejects this program, with the following message:

```
The method add(capture#1-of ?) in the type List<capture#1-of ?> is not
applicable for the arguments (Object)
```

A) Explain why we obtain such an error.

B) Fix the program by using a generic type for the parameter of method `add` and constraining the wildcard appropriately.

C) We can use the following alternative signature for `add`:

```
public <V> void add(V value, List<V> list)
```

Is this solution more restricted than the one obtained using the wildcard?

D) Consider the following methods:

```
public <V> void addAllX(List<V> v, List<? super V> l) {
   for(V el : v) l.add(el);
}
public <V> void addAllY(List<V> v, List<V> l) {
   for(V el : v) l.add(el);
}
```

Method `addAllX` is less restrictive than `addAllY`. Provide an example to prove this claim.

Task 6

A C++ template class can inherit from its template argument:

```
template <typename T>
class SomeClass : public T { ... }
```

A) Using this technique and given the following class definition

```
class Cell {
public:
   virtual void setVal(int x) { x_ = x; }
   virtual int value() { return x_; }
private:
   int x_{};
}
```

write two template classes that can be used as “mixins” for class `Cell`

- `Doubling` - doubles the value stored in the cell.
- `Counting` - counts the number of times the value of the cell was read.

Do not use multiple inheritance. It should be possible to use the classes like this:

```
auto c = new Doubling<Counting<Cell>>(); // instantiation
c->setVal(5);
c->value(); // returns 10
c->numRead(); // returns 1
```

B) Describe how the instantiation above will look like.

C) How does this concept of mixins in C++ differ from Scala traits?