Generalized type constraints

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Based on Generalized type constraints in Scala

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How is it useful?

- ▶ on Option

  ```
  def flatten[B](implicit ev: A <:< Option[B]):
      Option[B]
  ```

- ▶ on Traversable

  ```
  def toMap[K, V](implicit ev: A <:< (K, V)): Map[K, V]
  ```

- ▶ on Try

  ```
  def flatten[U](implicit ev: T <:< Try[U]): Try[U]
  ```

What do they have in common?

- ▶ implicit parameter list, with a single parameter called ev
- ▶ type of this parameter is of the form Type1 <:< Type2

Meaning

```
Type1 <:< Type2
```

Meaning

Make sure that Type1 is a subtype of Type2, or else report an error.

Example 1

```scala
scala> val oo: Option[Option[Int]] = Some(Some(42))
oo: Option[Option[Int]] = Some(Some(42))

scala> oo.flatten
res1: Option[Int] = Some(42)
```

Example 2

```scala
scala> val oi: Option[Int] = Some(42)
oi: Option[Int] = Some(42)

scala> oi.flatten
<console>:21: error: Cannot prove that Int <:< Option[B].
        oi.flatten
```

Plain example

```scala
scala> def tuple[T, U](t: T, u: U) = (t, u)
scala> tuple("Lincoln", 42)
res1: (String, Int) = (Lincoln,42)
```

Example with upper bound

```scala
scala> def tupleIfSubtype[T <: U, U](t: T, u: U) = (t, u)
scala> tupleIfSubtype("Lincoln", 42)
```

Example with upper bound

```scala
scala> def tupleIfSubtype[T <: U, U](t: T, u: U) = (t, u)
scala> tupleIfSubtype("Lincoln", 42)


res2: (String, Any) = (Lincoln,42)
```

Puzzler

Why?

type inference solves a constraint system

Generalized type constraints
└─ Type bound usage
   └─ Constraint system

Puzzler

Why?

type inference solves a constraint system

so given

```scala
scala> def tupleIfSubtype[T <: U, U](t: T, u: U) = (t, u)
scala> tupleIfSubtype("Lincoln", 42)
res2: (String, Any) = (Lincoln,42)
```

the constraints are satisfied with

- ▶ String is a String of course
- ▶ Int is a subtype of Any
- ▶ String is also a subtype of Any

Generalized type constraints
└─ How does it work?
  └─ Simplified

Simplified implementation

```
trait <::<[-From, +To]

object <::< {
  implicit def conforms[A]: A <::< A = new <::<[A,A]{}
}
```

Generalized type constraints
└─ How does it work?
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Simplified implementation

```
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object <::< {
  implicit def conforms[A]: A <::< A = new <::<[A,A]{}
}


e.g.

def tupleIfSubtype[T, U](t: T, u: U)(implicit ev: T <::<
    U) = (t, u)

tupleIfSubtype(new Apple(), new
    Fruit())(<::<.conforms[Fruit])
tupleIfSubtype(new Apple(), new
    Fruit())(<::<.conforms[Apple])
```

Why does it work?

- Variance of the type parameters of `trait <::<[-From, +To]` is similar to a function: require less, provide more: $F \Rightarrow T$
- $\rightarrow$ compiler tries to find a type `<::<[A, A]` that conforms to e.g. `<::<[Apple, Fruit]`

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- $A \Rightarrow A$?

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Generalized type constraints
└─ How does it work?
  └─ Explained

What constraints must be satisfied?

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- $A \Rightarrow A$?
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  - A must be a supertype of F: `A >: F` or `F <: A`
  - A must be a subtype of T: `A <: T`
- $\rightarrow$ `F <: A <: T`
- $\rightarrow$ `F <: T`

Generalized type constraints
└─ How does it work?
  └─ Implementation

Real implementation

- adds a nice error message:
  `@implicitNotFound(msg = "Cannot prove that ${From} <:< ${To}.")`

- extends function:
  `class <:<[-From, +To] extends (From =>To)`

- uses a singleton value:
  `val singleton_<:< =`
  `new <:<[Any,Any] { def apply(x: Any): Any = x }`

- and typecast it:
  `singleton_<:<.asInstanceOf[A <:< A]`

Other

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- alternative: implicit class or type class $\rightarrow$ more overhead
- exact type =:=[From, To] vs <:<[-From, +To]
- not subtype <:!<:

```scala
def unexpected : Nothing = sys.error("Unexpected
    invocation")
@scala.annotation.implicitNotFound("${A} must not be
    a subtype of ${B}")
trait <:!<[A, B] extends Serializable
implicit def nsub[A, B] : A <:!< B = new <:!<[A, B] {}
implicit def nsubAmbig1[A, B >: A] : A <:!< B =
    unexpected
implicit def nsubAmbig2[A, B >: A] : A <:!< B =
    unexpected
```