Solid Code with Liquid Types!

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The untyped* world

```
def sumlist(xs):
    total = 0
    for x in xs:
        total += x
    return total
```

*There is no such thing as an untyped language

The untyped* world

```
>>> sumlist([1, 2, 3])
6
```

The untyped* world

```
>>> sumlist(“Hello Cadiz”)

unsupported operand type(s)
for +=: 'int' and 'str'
```

Defensive programming

```
def sumlist(xs):
    if not isinstance(xs, list):
        raise ValueError("no thanks!")
    for x in xs:
        if not isinstance(x, (int, float)):
            raise ValueError("no thanks!")
     ...
```

The typed world

```
sumList :: [Int] → [Int]
sumList []     = 0
sumList (x:xs) = x + sumList xs
```

The typed world

```
sumList “Hello Cadiz”

No instance for ‘Num Char’ arising
from a use of ‘sum’
```

Are we typed enough?

```
head :: [Int] → Int
head (x:_) = x
```

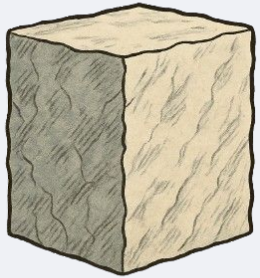
Sort of

```
head []

*** Exception: <file>:n:m-r:
Non-exhaustive patterns in function head
```

Many types

```
data NEList a
  = Singleton a
  | Cons a (NEList a)

head :: NEList a → NEList a
head (Singleton a) = a
head (Cons a xs)   = a
```

Refinement types and Liquid Haskell



```
Int
```

```
{ v:Int | v % 2 = 0 }
```

Refinement type = Base type + predicate

In Liquid Haskell predicates are expressions **(no quantifiers)**

A family of types

```
head :: { xs:[Int] | len xs > 0 } → Int
head (x:_) = x
```

With subtyping

$$\frac{\forall v.\phi_1(v) \Rightarrow \phi_2(v)}{\{v : T \mid \phi_1(v)\} \preceq \{v : T \mid \phi_2(v)\}}$$

Ok! Let’s see them in action!