# Haskell: Making Types

## Principles of Programming Languages

Colorado School of Mines

https://lambda.mines.edu

# Learning Group Activity

Review the LGA with your group. Yadda yadda yadda.

# The data Keyword

In Haskell, using the `data` keyword lets us define our own types. For example, consider the `Bool` type, which could be defined as so:

```haskell
data Bool = True | False
```

This reads, the data type `Bool` can be the value `True` or `False`.

# A Simple Data Type

Suppose we wanted to define a `Point` type which stores two `Floats`:

```
data Point = Point Float Float
```

That `Point` on the RHS of the = is the name of the constructor. This could be a different name than the type, but typically you will find it shares the same name.

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To make a `Point`:

```
(Point 10.5 11.2)
```

# Why Not Just Tuples?

While it is true you could just use a `(Float, Float)` tuple to represent your points, consider the downsides:

- **Type Safety:** What about `(Float, Float)` tuples that don't refer to points? Should these work in your methods made for points?
- **Readability:** Would another programmer reading your code understand that the 2-tuple referred to points? Maybe for points but harder for other types (what about a type `Person` that describes features of a person?)

# Another Example

```
data Shape = Circle Point Float | Rectangle Point Point
```

We can refer to our type in our functions by pattern matching:

```
area :: Shape -> Float
area (Circle _ r) = pi * r^2
area (Rectangle (Point x1 y1) (Point x2 y2)) = (x2 - x1) * (y2 - y1)
```

**Activity**

With your learning group, write a perimeter function. Then, extend the Shape data type to allow for a triangle (how you store this is up to you, right triangles are OK) and extend your perimeter function.

# Record Syntax

You could imagine writing functions to help you get the center or radius of a `Circle`:

```
center (Circle c _) = c
radius (Circle _ r) = r
```

Fortunately, *you don't have to do this.* Haskell provides a **Record Syntax** that defines these functions for you, and makes your code a bit more readable:

```
data Circle = Circle { center :: Point, radius :: Float }
```

This also gives us access to a new constructor syntax:

```
Circle {center=(Point 1 1), radius=10}
```

# Type Parameters

Type parameters allow your type to take another data type. A simple example is the `Maybe` type builtin to Haskell:

```
data Maybe a = Nothing | Just a
```

How does this read? `Maybe` is either `Nothing` or the type specified by **a**.

As another example, suppose you wanted to define a 3D `Vector` data type that could work on any type:

```
data Vector a = Vector a a a
```

# Deriving Typeclasses

Suppose we want to be able to print our circles to the screen:

```
data Point = Point Float Float deriving (Show)

data Circle = Circle {
                center :: Point,
                radius :: Float
              } deriving (Show)
```

Now...

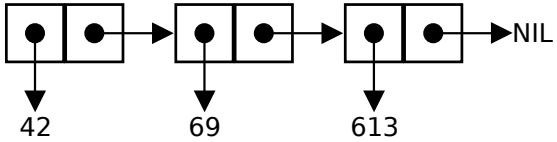
```
GHCi> Circle (Point 1 1) 1
Circle (Point 1 1) 1
```

We can use this to derive other attributes:

```
data Point = Point Float Float deriving (Show, Eq)
```

# How are lists really defined?

One of the most fundamental types in programming languages is the **cons cell**. A cons cell is simply an ordered pair where either element may be a pointer to another.




Haskell uses cons cells to make lists as shown in the image above. In fact, `[42,69,113]` is really just a fancy syntax for `42:69:113:[]`!

# Recursive Types

Suppose we wanted to make our own list type:

```
data List a = Empty | Cons a (List a)
```

Then, we can build "lists" using this notation:

```
-- Equivalent to [5]
(Cons 5 Empty)

-- Equivalent to [4,5]
(Cons 4 (Cons 5 Empty))

-- Equivalent to [3,4,5]
(Cons 3 (Cons 4 (Cons 5 Empty)))
```

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What do we get if we rename `Cons` to `:` and `Empty` to `[]`?

# Activity: Tree Type

With your learning group, create a `Tree` type that defines a binary tree.

**Hint:** Go back to our cons cell definition.

Once done, think about how you could extend the type to support $n$-ary trees.