

# CMSC 330: Organization of Programming Languages

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## Functional Programming with OCaml

# What is a functional language?

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A functional language:

- defines computations as **mathematical functions**
- avoids mutable **state**

**State:** the information maintained by a computation

**Mutable:** can be changed

# Functional vs. Imperative

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## Functional languages:

- *Higher* level of abstraction
- *Easier* to develop robust software
- *Immutable* state: easier to reason about software

## Imperative languages:

- *Lower* level of abstraction
- *Harder* to develop robust software
- *Mutable* state: harder to reason about software

# Imperative Programming

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Commands specify **how to compute** by destructively changing state:

```
x = x+1;  
a[i] = 42;  
p.next = p.next.next;
```

Functions/methods have **side effects**:

```
int wheels(Vehicle v) {  
    v.size++;  
    return v.numWheels;  
}
```

# Mutability

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## The **fantasy** of mutability:

- It's easy to reason about: the machine does this, then this...

## The **reality** of mutability:

- **Machines are good** at complicated manipulation of state
- **Humans are not** good at understanding it!
  - mutability **breaks referential transparency**: ability to replace an expression with its value without affecting the result
  - In math, if  $f(x)=y$ , then you can substitute  $y$  anywhere you see  $f(x)$
  - In imperative languages, you cannot:  $f$  might have **side effects**, so computing  $f(x)$  at one time might result in different value at another

# Mutability

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## The **fantasy** of mutability:

- There is a single state
- The computer does one thing at a time

## The **reality** of mutability:

- There is **no single state**
  - Programs have **many threads**, spread across many cores, spread across **many processors**, spread across **many computers**...
  - each with its **own view of memory**
- There is no single program
  - Most applications do many things at one time

# Functional programming

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## Expressions specify what to compute

- Variables never change value
- Functions (almost) never have side effects

## The reality of **immutability**:

- No need to think about state
- Easier (and more powerful) ways to build **correct** programs and concurrent programs

# Why study functional programming?

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## Functional languages predict the future:

- **Garbage collection**
  - Java [1995], LISP [1958]
- **Generics**
  - Java 5 [2004], ML [1990]
- **Higher-order functions**
  - C#3.0 [2007], Java 8 [2014], LISP [1958]
- **Type inference**
  - C++11 [2011], Java 7 [2011] and 8, ML [1990]
- **Pattern matching**
  - ML [1990], Scala [2002]



# Why study functional programming?

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## Functional languages in the real world

- **Java 8** 
  - **F#, C# 3.0, LINQ**  Microsoft
  - **Scala**   **Linked in** 
  - **Haskell**    at&t
  - **Erlang**    T-Mobile
  - **OCaml**  **Bloomberg**   Jane Street
- <https://ocaml.org/learn/companies.html>

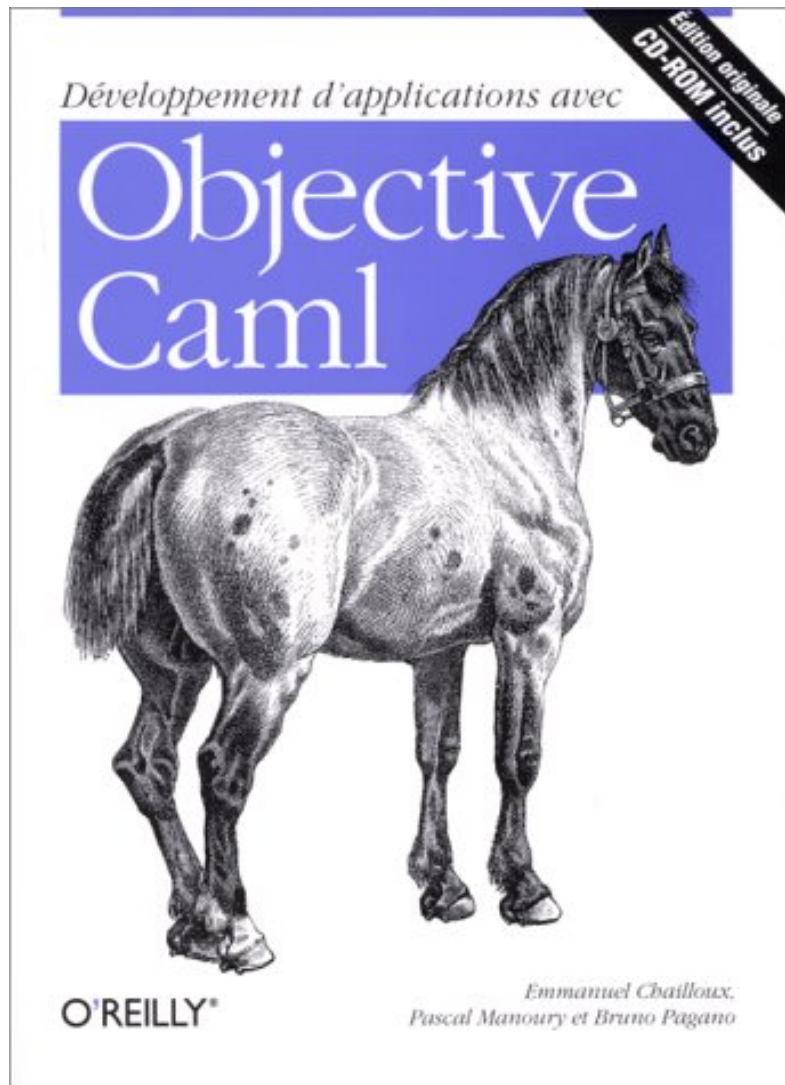
# ML-style (Functional) Languages

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- ML (Meta Language)
  - Univ. of Edinburgh, 1973
  - Part of a theorem proving system LCF
- Standard ML
  - Bell Labs and Princeton, 1990; Yale, AT&T, U. Chicago
- OCaml (Objective CAML)
  - INRIA, 1996
    - French Nat'l Institute for Research in Computer Science
  - O is for “objective”, meaning objects, which we'll ignore
- Haskell (1998): *lazy* functional programming
- Scala (2004): functional and OO programming

# Useful Information on OCaml language

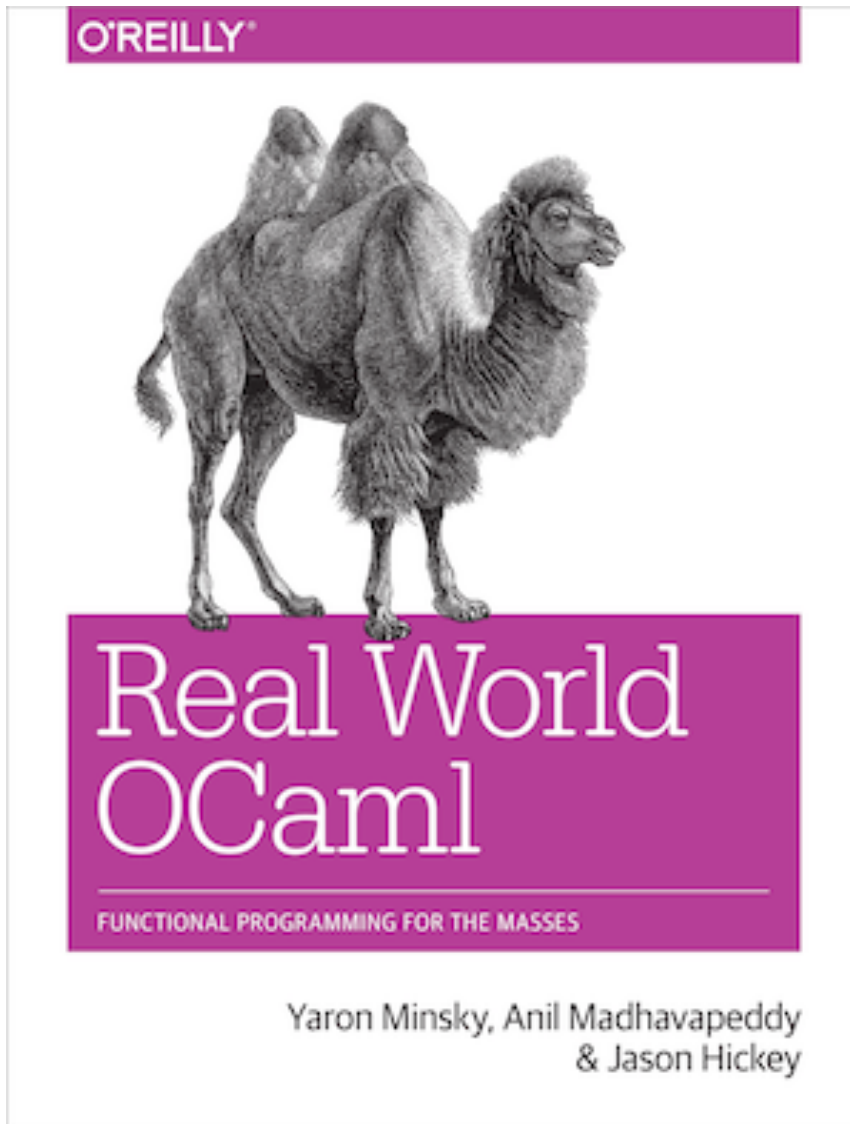
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- Translation available on the class webpage
  - *Developing Applications with Objective Caml*
- Webpage also has link to another book
  - *Introduction to the Objective Caml Programming Language*

# More Information on OCaml

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- Book designed to introduce **and advance** understanding of OCaml
  - Authors use OCaml in the real world
  - Introduces new libraries, tools
- Free HTML online
  - [realworldocaml.org](http://realworldocaml.org)

# Features of ML

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- First-class functions
  - Functions can be data, too: parameters and return values
- Favor **immutability** (“assign once”)
- **Data types** and **pattern matching**
  - Convenient for certain kinds of data structures
- **Type inference**
  - No need to write types in the source language
    - But the language is statically typed
  - Supports **parametric polymorphism**
    - *Generics* in Java, *templates* in C++
- **Exceptions**
- **Garbage collection**