Course Motivation
(Did you think I forgot? 😊)

- Why learn the fundamental concepts that appear in all (most?) languages?
- Why use languages quite different from C, C++, Java, Python?
- Why focus on functional programming?
- Why use ML, Racket, and Ruby in particular?
- Not: Language X is better than Language Y

[You won’t be tested on this stuff]

Summary
- No such thing as a “best” PL
- Fundamental concepts easier to teach in some (multiple) PLs
- A good PL is a relevant, elegant interface for writing software
  - There is no substitute for precise understanding of PL semantics
- Functional languages have been on the leading edge for decades
  - Ideas have been absorbed by the mainstream, but very slowly
  - First-class functions and avoiding mutation increasingly essential
  - Meanwhile, use the ideas to be a better C/Java/PHP hacker
- Many great alternatives to ML, Racket, and Ruby, but each was chosen for a reason and for how they complement each other

Cars / Shoes

Cars are used for rather different things:
- Winning a Formula 1 race
- Taking kids to soccer practice
- Off-roading
- Hauling a mattress
- Getting the wind in your hair
- Staying dry in the rain

Shoes:
- Playing basketball
- Going to a formal
- Going to the beach

More on cars

- A good mechanic might have a specialty, but also understands how “cars” (not a particular make/model) work
  - The upholstery color isn’t essential (syntax)
- A good mechanical engineer really knows how cars work, how to get the most out of them, and how to design better ones
  - I don’t have a favorite kind of car or a favorite PL
- To learn how car pieces interact, it may make sense to start with a classic design rather than the latest model
  - A popular car may not be best
  - May especially not be best for learning how cars work
Why semantics and idioms

This course focuses as much as it can on semantics and idioms

• Correct reasoning about programs, interfaces, and compilers requires a precise knowledge of semantics
  – Not “I feel that conditional expressions might work like this”
  – Not “I like curly braces more than parentheses”
  – Much of software development is designing precise interfaces; what a PL means is a really good example

• Idioms make you a better programmer
  – Best to see in multiple settings, including where they shine
  – See Java in a clearer light even if I never show you Java

Hamlet

The play Hamlet:
  – Is a beautiful work of art
  – Teaches deep, eternal truths
  – Is the source of some well-known sayings
  – Makes you a better person

Continues to be studied centuries later even though:
  – The syntax is really annoying to many
  – There are more popular movies with some of the same lessons
  – Reading Hamlet will not get you a summer internship

All cars are the same

• To make it easier to rent cars, it is great that they all have steering wheels, brakes, windows, headlights, etc.
  – Yet it is still uncomfortable to learn a new one
  – Can you be a great driver if you only ever drive one car?

• And maybe PLs are more like cars, trucks, boats, and bikes

• So are all PLs really the same…

Are all languages the same?

Yes:
  – Any input-output behavior implementable in language X is implementable in language Y [Church-Turing thesis]
  – Java, ML, and a language with one loop and three infinitely-large integers are “the same”

Yes:
  – Same fundamentals reappear: variables, abstraction, one-of types, recursive definitions, …

No:
  – The human condition vs. different cultures (travel to learn more about home)
  – The primitive/default in one language is awkward in another
  – Beware “the Turing tarpit”

Functional Programming

Why spend 60-80% of course using functional languages:
  – Mutation is discouraged
  – Higher-order functions are very convenient
  – One-of types via constructs like datatypes

Because:
1. These features are invaluable for correct, elegant, efficient software (great way to think about computation)
2. Functional languages have always been ahead of their time
3. Functional languages well-suited to where computing is going

Most of course is on (1), so a few minutes on (2) and (3) …

Ahead of their time

All these were dismissed as “beautiful, worthless, slow things PL professors make you learn”

• Garbage collection (Java didn’t exist in 1995, PL courses did)
• Generics (List<T> in Java, C#), much more like SML than C++
• XML for universal data representation (like Racket/Scheme/LISP/…)
• Higher-order functions (Ruby, Javascript, C#, …)
• Type inference (C#, Scala, …)
• Recursion (a big fight in 1960 about this – I’m told ☺)
• …
**The future may resemble the past**

Somehow nobody notices we are right... 20 years later

- “To conquer” versus “to assimilate”
- Societal progress takes time and muddles “taking credit”
- Maybe pattern-matching, currying, hygienic macros, etc. will be next

**Recent-ish Surge, Part 1**

Other popular functional PLs (alphabetized, pardon omissions)

- Clojure http://clojure.org
- Erlang http://www.erlang.org
- F# http://tryfsharp.org
- Haskell http://www.haskell.org
- OCaml http://ocaml.org
- Scala http://www.scala-lang.org

Some “industry users” lists (surely more exist):

- http://www.haskell.org/haskellwiki/Haskell_in_industry
- http://ocaml.org/companies.html
- In general, see http://cufp.org

**Recent-ish Surge, Part 2**

Popular adoption of concepts:

- C#, LINQ (closures, type inference, …)
- Java 8 (closures)
- MapReduce / Hadoop
  - Avoiding side-effects essential for fault-tolerance here
- ...

**Why a surge?**

My best guesses:

- Concise, elegant, productive programming
- JavaScript, Python, Ruby helped break the Java/C/C++
  hegemony
- Avoiding mutation is the easiest way to make concurrent and
  parallel programming easier
  - In general, to handle sharing in complex systems
- Sure, functional programming is still a small niche, but there is
  so much software in the world today even niches have room

**The languages together**

SML, Racket, and Ruby are a useful combination for us

<table>
<thead>
<tr>
<th></th>
<th>dynamically typed</th>
<th>statically typed</th>
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</thead>
<tbody>
<tr>
<td>functional</td>
<td>Racket</td>
<td>SML</td>
</tr>
<tr>
<td>object-oriented</td>
<td>Ruby</td>
<td>Java</td>
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ML: polymorphic types, pattern-matching, abstract types & modules

Racket: dynamic typing, “good” macros, minimalist syntax, eval

Ruby: classes but not types, very OOP, mixins
  [and much more]

Really wish we had more time:

**Haskell**: laziness, purity, type classes, monads

**Prolog**: unification and backtracking
  [and much more]

**But why not…**

Instead of SML, could use similar languages easy to learn after:

- OCaml: yes indeed but would have to port all my materials ☹
  - And a few small things (e.g., second-class constructors)
- F#: yes and very cool, but needs a .Net platform
  - And a few more small things (e.g., second-class
    constructors, less elegant signature-matching)
- Haskell: more popular, cooler types, but lazy semantics and
  type classes from day 1

Admittedly, SML and its implementations are showing their age
  (e.g., andalso and less tool support), but it still makes for a fine
  foundation in statically typed, eager functional programming
**But why not…**

Instead of Racket, could use similar languages easy to learn after:

- Scheme, Lisp, Clojure, …

Racket has a combination of:

- A modern feel and active evolution
- “Better” macros, modules, structs, contracts, …
- A large user base and community (not just for education)
- An IDE tailored to education

Could easily define our own language in the Racket system

- Would rather use a good and vetted design

**But why not…**

Instead of Ruby, could use another language:

- Python, Perl, JavaScript are also dynamically typed, but are not as “fully” OOP, which is what I want to focus on
  - Python also does not have (full) closures
  - JavaScript also does not have classes but is OOP

- Smalltalk serves my OOP needs
  - But implementations merge language/environment
  - Less modern syntax, user base, etc.

**Is this real programming?**

- The way we use ML/Racket/Ruby can make them seem almost “silly” precisely because lecture and homework focus on interesting language constructs
- “Real” programming needs file I/O, string operations, floating-point, graphics, project managers, testing frameworks, threads, build systems, …
  - Many elegant languages have all that and more
    - Including Racket and Ruby
  - If we used Java the same way, Java would seem “silly” too

**A note on reality**

Reasonable questions when deciding to use/learn a language:

- What libraries are available for reuse?
- What tools are available?
- What can get me a job?
- What does my boss tell me to do?
- What is the de facto industry standard?
- What do I already know?

Our course by design does not deal with these questions

- You have the rest of your life for that
- And technology leaders affect the answers