



# CSE341: Programming Languages

## Lecture 4

### Records, Datatypes, Case Expressions

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Spring 2016

# *Five different things*

1. **Syntax:** How do you write language constructs?
2. **Semantics:** What do programs mean? (Evaluation rules)
3. **Idioms:** What are typical patterns for using language features to express your computation?
4. **Libraries:** What facilities does the language (or a well-known project) provide “standard”? (E.g., file access, data structures)
5. **Tools:** What do language implementations provide to make your job easier? (E.g., REPL, debugger, code formatter, ...)
  - Not actually part of the language

These are 5 separate issues

- In practice, all are essential for good programmers
- Many people confuse them, but shouldn't

# *Our Focus*

This course focuses on semantics and idioms

- Syntax is usually uninteresting
  - A fact to learn, like “The American Civil War ended in 1865”
  - People obsess over subjective preferences
- Libraries and tools crucial, but often learn new ones “on the job”
  - We are learning semantics and how to use that knowledge to understand all software and employ appropriate idioms
  - By avoiding most libraries/tools, our languages may look “silly” but so would *any* language used this way

# *How to build bigger types*

- Already know:
  - Have various *base types* like `int` `bool` `unit` `char`
  - Ways to build (nested) *compound types*: tuples, lists, options
- Coming soon: more ways to build compound types
- First: 3 most important type building blocks in *any* language
  - “Each of”: A `t` value contains *values of each of* `t1` `t2` ... `tn`
  - “One of”: A `t` value contains *values of one of* `t1` `t2` ... `tn`
  - “Self reference”: A `t` value can refer to other `t` values

Remarkable: A lot of data can be described with just these building blocks

Note: These are not the common names for these concepts

# Examples

- Tuples build each-of types
  - `int * bool` contains an `int` *and* a `bool`
- Options build one-of types
  - `int option` contains an `int` *or* it contains no data
- Lists use all three building blocks
  - `int list` contains an `int` *and* another `int list` *or* it contains no data
- And of course we can nest compound types
  - `((int * int) option * (int list list)) option`

# *Rest of this Lecture*

- Another way to build each-of types in ML
  - *Records*: have named *fields*
  - Connection to tuples and idea of *syntactic sugar*
- A way to build and use our own one-of types in ML
  - For example, a type that contains an **int** or a **string**
  - Will lead to *pattern-matching*, one of ML's coolest and strangest-to-Java-programmers features
- Later in course: How OOP does one-of types
  - Key contrast with procedural and functional programming

# Records

*Record values* have fields (any name) holding values

```
{ f1 = v1, ..., fn = vn }
```

*Record types* have fields (and name) holding types

```
{ f1 : t1, ..., fn : tn }
```

The order of fields in a record value or type never matters

- REPL alphabetizes fields just for consistency

Building records:

```
{ f1 = e1, ..., fn = en }
```

Accessing components:

```
#myfieldname e
```

(Evaluation rules and type-checking as expected)

# Example

```
{name = "Matai", id = 4 - 3}
```

Evaluates to

```
{id = 1, name = "Matai"}
```

And has type

```
{id : int, name : string}
```

If some expression such as a variable **x** has this type, then get fields with:

```
#id x      #name x
```

Note we did not have to declare any record types

– The same program could also make a

```
{id=true, ego=false} of type {id:bool, ego:bool}
```



# *By name vs. by position*

- Little difference between  $(4, 7, 9)$  and  $\{f=4, g=7, h=9\}$ 
  - Tuples a little shorter
  - Records a little easier to remember “what is where”
  - Generally a matter of taste, but for many (6? 8? 12?) fields, a record is usually a better choice
- A common decision for a construct’s syntax is whether to refer to things *by position* (as in tuples) or *by some (field) name* (as with records)
  - A common hybrid is like with Java method arguments (and ML functions as used so far):
    - Caller uses *position*
    - Callee uses *variables*
    - Could totally do it differently; some languages have

# *The truth about tuples*

Previous lecture gave tuples syntax, type-checking rules, and evaluation rules

But we could have done this instead:

- Tuple syntax is just a different way to write certain records
- $(e_1, \dots, e_n)$  is another way of writing  $\{1=e_1, \dots, n=e_n\}$
- $t_1 * \dots * t_n$  is another way of writing  $\{1:t_1, \dots, n:t_n\}$
- In other words, records with field names 1, 2, ...

In fact, this is how ML actually defines tuples

- Other than special syntax in programs and printing, they don't exist
- You really can write  $\{1=4, 2=7, 3=9\}$ , but it's bad style

# *Syntactic sugar*

“Tuples are just **syntactic sugar** for records with fields named 1, 2, ... n”

- *Syntactic*: Can describe the semantics entirely by the corresponding record syntax
- *Sugar*: They make the language sweeter 😊

Will see many more examples of syntactic sugar

- They simplify *understanding* the language
- They simplify *implementing* the language

Why? Because there are fewer semantics to worry about even though we have the syntactic convenience of tuples

Another example we saw: **andalso** and **orelse** vs. **if then else**

# *Datatype bindings*

A “strange” (?) and totally awesome (!) way to make one-of types:

- A `datatype` binding

```
datatype mytype = TwoInts of int * int
                 | Str of string
                 | Pizza
```

- Adds a new type `mytype` to the environment
- Adds *constructors* to the environment: `TwoInts`, `Str`, and `Pizza`
- A constructor is (among other things), a function that makes values of the new type (or is a value of the new type):
  - `TwoInts : int * int -> mytype`
  - `Str : string -> mytype`
  - `Pizza : mytype`

# The values we make

```
datatype mytype = TwoInts of int * int
                 | Str of string
                 | Pizza
```

- Any value of type `mytype` is made from *one of* the constructors
- The value contains:
  - A “tag” for “which constructor” (e.g., `TwoInts`)
  - The corresponding data (e.g., `(7, 9)`)
- Examples:
  - `TwoInts (3+4, 5+4)` evaluates to `TwoInts (7, 9)`
  - `Str (if true then “hi” else “bye”)` evaluates to `Str (“hi”)`
  - `Pizza` is a value

# *Using them*

So we know how to *build* datatype values; need to *access* them

There are *two* aspects to accessing a datatype value

1. Check what *variant* it is (what constructor made it)
2. Extract the *data* (if that variant has any)

Notice how our other one-of types used functions for this:

- `null` and `isSome` check variants
- `hd`, `tl`, and `valOf` extract data (raise exception on wrong variant)

ML *could* have done the same for datatype bindings

- For example, functions like “`isStr`” and “`getStrData`”
- Instead it did something better

# Case

ML combines the two aspects of accessing a one-of value with a *case expression* and *pattern-matching*

- Pattern-matching much more general/powerful (Lecture 5)

Example:

```
fun f x = (* f has type mytype -> int *)
  case x of
    Pizza => 3
  | TwoInts (i1, i2) => i1+i2
  | Str s => String.size s
```

- A multi-branch conditional to pick branch based on variant
- Extracts data and binds to variables local to that branch
- Type-checking: all branches must have same type
- Evaluation: evaluate between **case ... of** and the right branch

# Patterns

In general the syntax is:

```
case e0 of
  p1 => e1
  | p2 => e2
  ...
  | pn => en
```

For today, each *pattern* is a constructor name followed by the right number of variables (i.e., `C` or `C x` or `C (x, y)` or ...)

- Syntactically most patterns (all today) look like expressions
- But patterns are not expressions
  - We do not evaluate them
  - We see if the result of `e0` *matches* them



# *Why this way is better*

0. You can use pattern-matching to write your own testing and data-extractions functions if you must
  - But do not do that on your homework
1. You cannot forget a case (inexhaustive pattern-match warning)
2. You cannot duplicate a case (a type-checking error)
3. You will not forget to test the variant correctly and get an exception (like `hd []`)
4. Pattern-matching can be generalized and made more powerful, leading to elegant and concise code