

CSE 341: Programming Languages

Section 1

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Thanks to Dan Grossman, Josiah Adams, and Cody A. Schroeder for the substantial majority of this content

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```
fun min(x,y) :=  
  if x <= y then x else y.
```

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```
Function min x y :=  
  if x <=? y then x else y.
```



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```
Function min x y :=  
  if x <=? y then x else y.
```

```
Goal  $\forall x y, \text{min } x y \leq x \wedge$   
       $\text{min } x y \leq y.$ 
```

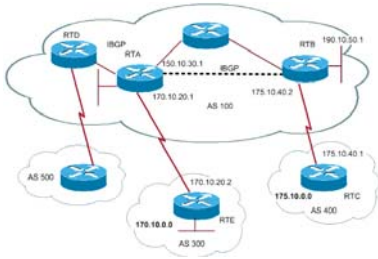
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```
Function min x y :=  
  if x <=? y then x else y.
```

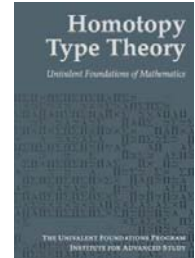
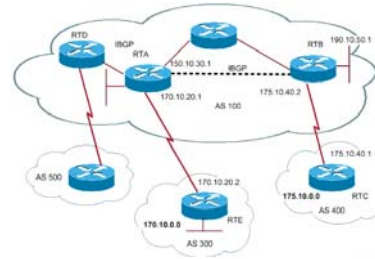
```
Goal  $\forall x y, \text{min } x y \leq x \wedge$   
       $\text{min } x y \leq y.$   
Proof.  
  intros; unfold min.  
  destruct (x <=? y) eqn:e.  
  - rewrite Nat.leb_le in e.  
    omega.  
  - rewrite leb_iff_conv in e.  
    omega.  
Qed.
```

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Today's Agenda

- ML Development Workflow
 - Emacs
 - Using `use`
 - The REPL (Read-Eval-Print Loop)
- More ML
 - Shadowing Variables
 - Debugging Tips
 - Boolean Operations
 - Comparison Operations

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Emacs Demo

- Recommended (not required) editor for this course
- Powerful, but the learning curve can at first be intimidating

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Using `use`

```
use "foo.sml";
```

- Enters bindings from the file `foo.sml`
 - Like typing the variable bindings one at a time in sequential order into the REPL (more on this in a moment)
- Result is `()` bound to variable `it`
 - Ignorable

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The REPL

- Read-Eval-Print-Loop is well named
- Conveniently run programs
 - Useful to quickly try something out
 - Save code for reuse by moving it into a persistent `.sml` file
- Expects semicolons
- For reasons discussed later, it's dangerous to reuse `use` without restarting the REPL session

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Debugging Errors

Your mistake could be:

- Syntax: What you wrote means nothing or not the construct you intended
- Type-checking: What you wrote does not type-check
- Evaluation: It runs but produces wrong answer, or an exception, or an infinite loop

Keep these straight when debugging even if sometimes one kind of mistake appears to be another

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Play around

Best way to learn something: Try lots of things and don't be afraid of errors

Work on developing resilience to mistakes

- Slow down
- Don't panic
- Read what you wrote very carefully

Maybe watching me make a few mistakes will help...

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Shadowing of Variable Bindings

```
val a = 1; (* a -> 1 *)
val b = a; (* a -> 1, b -> 1 *)
val a = 2; (* a -> 2, b -> 1 *)
```

1. Expressions in variable bindings are evaluated “eagerly”
 - Before the variable binding “finishes”
 - Afterwards, the expression producing the value is irrelevant
1. Multiple variable bindings to the same variable name, or “shadowing”, is allowed
 - When looking up a variable, ML uses the latest binding by that name in the current environment
2. Remember, there is no way to “assign to” a variable in ML
 - Can only **shadow** it in a later environment
 - After binding, a variable's value is an immutable constant

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Try to Avoid Shadowing

```
val x = "Hello World";
val x = 2;           (* is this a type error? *)
val res = x * 2;    (* is this 4 or a type error? *)
```

- Shadowing can be confusing and is often poor style
- Why? Reintroducing variable bindings in the same REPL session may..
 - make it seem like *wrong* code is *correct*; or
 - make it seem like *correct* code is *wrong*.

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Using a Shadowed Variable

- Is it ever possible to use a shadowed variable? **Yes! And no...**
- It can be possible to uncover a shadowed variable when the latest binding goes out of scope

```
val x = "Hello World";
fun add1(x : int) = x + 1; (* shadow x in func body *)
val y = add1 2;
val z = x^"!!!"; (* "Hello World!!!" *)
```

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Use `use` Wisely

- **Warning:** Variable shadowing makes it dangerous to call `use` more than once without *restarting* the REPL session.
- It **may** be fine to repeatedly call `use` in the same REPL session, but unless you know what you're doing, *be safe!*
 - Ex: loading multiple distinct files (with independent variable bindings) at the beginning of a session
 - `use`'s behavior is well-defined, but even expert programmers can get confused
- Restart your REPL session before repeated calls to `use`

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Boolean Operations

Operation	Syntax	Type-checking	Evaluation
<code>andalso</code>	<code>e1 andalso e2</code>	<code>e1</code> and <code>e2</code> must have type <code>bool</code>	Same as Java's <code>e1 && e2</code>
<code>orelse</code>	<code>e1 orelse e2</code>	<code>e1</code> and <code>e2</code> must have type <code>bool</code>	Same as Java's <code>e1 e2</code>
<code>not</code>	<code>not e1</code>	<code>e1</code> must have type <code>bool</code>	Same as Java's <code>!e1</code>

- `not` is just a pre-defined function, but `andalso` and `orelse` must be built-in operations since they cannot be implemented as a function in ML.
 - Why? Because `andalso` and `orelse` “short-circuit” their evaluation and may not evaluate *both* `e1` and `e2`.
- Be careful to always use `andalso` instead of `and`.
- `and` is completely different. We will get back to it later.

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Style with Booleans

Language does not *need* `andalso`, `orelse`, or `not`

```
(* e1 andalso e2 *)
if e1
then e2
else false

(* e1 orelse e2 *)
if e1
then true
else e2

(* not e1 *)
if e1
then false
else true
```

Using more concise forms generally much better style

And definitely please do not do this:

```
(* just say e (!!!) *)
if e
then true
else false
```

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Comparisons

For comparing `int` values:

`= <> > < >= <=`

You might see weird error messages because comparators can be used with some other types too:

- `> < >= <=` can be used with `real`, but not `1 int` and `1 real`
- `= <>` can be used with any “equality type” but not with `real`
 - Let’s not discuss equality types yet

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