Introduction	Static vs. Dynamic Binding	Value	Typing	Location	Scoping
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Variables

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Objectives You should be able	to				

Variables have many different attributes. These attributes can become *bound* to the variable at different times.

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- Explain the difference between static and dynamic binding.
 - Of value
 - Of types
 - Of location
 - Of scoping (!)
- Give examples of implicit and explicit declaration.
- Give an example of aliasing is.

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What Is a Variable?

Mathematically

Variables represent a (possibly unknown) quantity or value. They usually are part of a model (or abstraction) of some concept or system.

$$f(\mathbf{x}) = 2^{i\pi} - \mathbf{x}$$

Programming

Variables are implementations of mathematical variables. (Has anyone here read Plato?)

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Static vs. Dynamic Binding

Static Binding

Attribute is **bound** at compile time.

- Allows the compiler to "hard code" information about the variable into the executable code
- Allows the compiler to perform optimizations based on its knowledge of the variable

Dynamic Binding

Attribute is **bound** at run time.

- A variable's attribute could change during the course of execution, or remain undetermined – very flexible.
- Information about the variable is usually stored with it.
- Sometimes we *don't know* the value of the attribute at compile time.

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Value					
► The	e value attribute of a variable	is most likely to	be dynamic.		
Son	netimes we want the value to	be static. (Not	to be confused w	ith the static ke	vword

in C.)

Static Value

```
const int i = 2;
1
2
  int foo(int j) { return i * j; }
3
4
  int bar() {
5
    int i = 10;
6
    i = foo(i);
7
    return i;
8
  }
9
```

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Static Typing

- Static typing: the type of variables are known at compile time.
- This makes many operations very efficient.

1 int sqr(int i) { 1 movi r1, val(i)
2 2 2 movi r2, val(i)
3 return i * i; 3 multi r1,r2,r3
4 } 4 pushi r3

• The compiler can catch errors: improving programmer reliability.

```
string s = "hi";
bool b = true;
if s then printf("4") else printf("9");
```

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Dynamic Typing

Some languages (e.g., BASIC, PERL most shell languages, TCL) use dynamic typing.

```
1 #!/usr/bin/perl
2
```

```
3 $i = "The answer is ";
```

```
4 print "$i";
```

```
5
```

```
6 $i = 42;
```

```
7 print "$i\n";
```

Actually, PERL types are partially dynamic. Scalars, arrays, and hashes are represented with different syntax.

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Polymorphism

• We can have both the advantages of strong typing *and* dynamic typing at the same time!

Overloading

```
int identity(int i) { return i; }
double identity(double x) { return x; }
```

Parameterized

```
template <class T>
T ident(T &i) { return i; }
```

Automatic

let id x = x;; val id : 'a -> 'a = <fun>

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Location

- Heap allocated variables completely dynamic
- Stack allocated variables partially static "stack relative" allocation

```
int length() {
    int i = 10;
    String s = new String("hello");
    return i + length(s);
  }
```

Weird Language

There is one language in which *all* variables – even function arguments – are allocated statically!

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Fortran

The Problem

- First released on the IBM 704 in 1957. It had core memory (equivalent to 18,432 bytes) and a 12k FLOP processor.
- Can we use a high level language and translate it to machine code?

The Solution: Hard-Code Variable Locations

- This made FORTRAN almost as fast as assembly.
- It is still the language of choice for numerical computation.
- Downside you don't get recursion. (Modern FORTRAN fixes this.)

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Aliasing

It is possible for multiple variables to refer to the same location.

```
int i = 20;
void inc(int &x) {
    x = x + 1;
}
// after this i and x will be the same!
... inc(i) ...
```

Use with extreme caution!

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Lifetime

- > Variables have a certain *scope* in the program for which they are valid.
- This allows us to have multiple variables with the same name.
- Usually the scope (or *lifetime*) is determined syntactically.

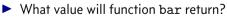
```
int foo(int i) {
1
    int j = 10;
2
    return j + 10;
3
  }
4
5
  int bar(int i) {
6
    int j = 20;
7
    return foo(j) + foo(i);
8
  }
9
```

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Example in C

Consider the following program:

```
int i = 2;
int foo() { return i * i; }
int bar() {
    int i = 10;
    return foo();
    }
```



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Example in Emacs LISP

```
(setq i 2) ;; global variable i = 2
(defun foo ()
(* i i))
(defun bar ()
(let ((i 10)) ;; local variable i = 10
(foo))) ;; call function foo
```

- What value will expression (bar) return?
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Static vs. Dynamic Scoping

- Most languages use static scoping.
- ► The first LISP implementations used *dynamic scoping*.
 - ► Today it is considered to be a Bad ThingTM by most sentient life-forms.
 - As always, some disagree ...
- It's too easy to modify the behavior of a function.
- Correct use requires knowledge of a function's internals.

Still used by Emacs LISP!