Structural Programming and Data Structures

Winter 2000

CMPUT 102: Simple Program

Dr. Osmar R. Zaïane

University of Alberta

Course Content

- **Introduction**
- Objects
- Methods
- Tracing Programs
- Object State
- Sharing resources
- Selection
- Repetition
- Vectors
- Testing/Debugging
- Arrays
- Searching
- Files I/O
- Sorting
- Inheritance
- Recursion

Lecture 6, 7, 8, 9: Simple Program

Objectives of Lecture 6

Programming Language Syntax

- Understand the types of errors that can be found in a Java program.
- Get a basic idea about what a Java compiler goes through to parse a Java program.
- Understand the importance of syntax rules.
- Translate the computation diagrams into Java statements.

Outline of Lecture 6

- Program errors
- Grammars, syntax and BNF
- Tokens
- Identifiers
- Literals
- Semantics

Program Errors

- There are four kinds of errors you can make when writing a program:
  - – insignificant errors
  - – compile-time errors
  - – run-time errors
  - – semantic errors

Syntax error

bug

Program - Adventure V0

```
public class Adventure {
/* Version 0
   This program is an arithmetic adventure game where an adventurer
   navigates rooms that contain treasure chests that are opened by
   correctly answering arithmetic problems.
*/
   public static void main(String args[]) {
   /* Program statements go here. */
        System.out.println("Welcome to the Arithmetic Adventure game.");
   }
}
```

Program - Adventure V0 without comments

```
public class Adventure {
   public static void main(String args[]) {
        System.out.println("Welcome to the Arithmetic Adventure game.");
   }
}
```

Insignificant Errors

If we mis-spell or leave out any red word this program works the same.

```
public class Adventure {
/* Version 0
   This program is an arithmetic adventure game where an adventurer
   navigates rooms that contain treasure chests that are opened by
   correctly answering arithmetic problems.
*/
   public static void main(String args[]) {
   /* Program statements go here. */
        System.out.println("Welcome to the Arithmetic Adventure game.");
   }
}
```

Compilation Errors

If we mis-spell or leave out any of these words the program won't compile.

```
public class Adventure {
/* Version 0
   This program is an arithmetic adventure game where an adventurer
   navigates rooms that contain treasure chests that are opened by
   correctly answering arithmetic problems.
*/
   public static void main(String args[]) {
   /* Program statements go here. */
        System.out.println("Welcome to the Arithmetic Adventure game.");
   }
}
```

Run-time Errors

If we leave out either of these word this program compiles but won't run.

```
public class Adventure {
/* Version 0
   This program is an arithmetic adventure game where an adventurer
   navigates rooms that contain treasure chests that are opened by
   correctly answering arithmetic problems.
*/
   public static void main(String args[]) {
   /* Program statements go here. */
        System.out.println("Welcome to the Arithmetic Adventure game.");
   }
}
```

Semantic Errors

If we leave out any words between quotation marks, the program works differently.

```
public class Adventure {
/* Version 0
   This program is an arithmetic adventure game where an adventurer
   navigates rooms that contain treasure chests that are opened by
   correctly answering arithmetic problems.
*/
   public static void main(String args[]) {
   /* Program statements go here. */
        System.out.println("Welcome to the Arithmetic Adventure game.");
   }
}
```

Outline of Lecture 6

- Program errors
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Need for LanguageRules

- How do we know what words to use in the program: "***public***", "***class***", "***static***", "***void***"?
- What order should we use for the words?
- How do we know if a program is expressed correctly in a programming language?

We need some rules for writing a program so that if we follow the rules the program will be correct.

Natural Language Rules

- Some language expressions make sense:
  - John ate the green apple.

- Some language expressions don't:
  - Walk red Mary eat square.

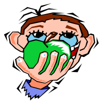
- There are rules that determine whether a natural language expression makes sense.

Grammars and Syntax

- The set of rules that define the **syntax** of legal constructs in a natural language is called a **grammar**.
- Here is a grammar rule for one simple English sentence structure:

<sentence> ::= <subject> <verb> <article> <adjective> <object>.

- Here is sentence that conforms to this grammar rule: **John ate the green apple.**



Notation

<sentence> ::= <subject> <verb> <article> <adjective> <object>.

- **::=** means "is defined as".

Sentence is defined as a subject followed by a verb followed by an article followed by an adjective followed by an object and terminated by a period.

- <sentence>, <subject>, <verb>, <article>,… are not real words but represent real words (tokens).

Backus-Naur Form (BNF)

- The notation:

  <sentence> ::= <subject> <verb> <article> <adjective> <object>.

  is called **Backus-Naur Form** (BNF).
- Words in < > are called non-terminals since they must be further defined.
- The symbols < > ::= are called meta-characters since they are part of the BNF language, not part of the target language.
- All other symbols (like the dot) are called terminals and must appear as shown.

Syntax Errors

- If there are syntax errors in a natural language sentence, it may still be understandable: **John ate the apple green**.
- In general, computer programs are much more sensitive to minor changes than natural languages.
- If there are syntax errors in a program, the compiler reports the errors and does not translate the program to machine language.

Common Syntactic Concepts

- Different natural languages share common concepts like: words, punctuation, phrases and sentences.
- Programming languages also share some common concepts.
- Three common concepts that are used to build larger syntactic structures are:
  - **tokens**
  - **identifiers**
  - **literals**

Outline of Lecture 6

- Program errors
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- Semantics

Tokens and Lexics

- Alphabetic symbols in many natural languages are combined into words.
- Alphabetic symbols in programming languages are combined into **tokens**.
- The rules for combining alphabetic symbols into tokens is often called **lexics**.
- The lexical rules are usually expressed independently from the grammar rules that describe how tokens can be combined into larger syntactic structures.

Token Classes

- In natural languages, there are different classes of words: nouns, verbs, etc. and the class of a word defines the syntactic use.
- In programming languages different **token groups** represent different kinds of basic constructs.
- A different set of lexical rules is used to identify each token group.

Scanning and Parsing

- The compiler uses a **scanner** (lexer) to read the characters in your source program one at a time and combine them into tokens.
- The compiler users a **parser** to recognize how these tokens are combined into more complex syntactic structures.
- Both compiler components use grammar rules to perform their tasks.

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Identifier Tokens

- An **identifier** is one of the most basic token classes in a programming language.
- The rules for identifiers vary between languages, but in Java, an identifier:
  - starts with a letter, underscore or dollar sign.
  - the initial character is followed by zero or more letters, digits, underscores or dollar signs.
- Valid: *taxRate R2D2 margin_size*
- Invalid: *98August jersey#*

BNF Rules for Java Identifiers

<identifier> ::= <initial> | <initial> <more>
<initial> ::= <letter> | _ | $
<more> ::= <final> | <more > <final>
<final> ::= <initial> | <digit>
<letter> ::= a | b | c | … z | A | B| … | Z
<digit> ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9

- Note that the bar is a meta-character that means “or”.
- Each line is called a grammar **production**.

Java BNF Identifier Example 1

- For example, R2D2 is legal since it is:

R 2 D 2
<letter> 2 D 2 using <letter> ::= R
<initial> 2 D 2 using <initial> ::= <letter>
<initial> <digit> D 2 using <digit> ::= 2
<initial> <final> D 2 using <final> ::= <digit>
<initial> <final> <letter> 2 using <letter> ::= D
<initial> <final> <initial> 2 using <initial> ::= <letter>
<initial> <final> <final> 2 using <final> ::= <initial>
<initial> <final> <final> <digit> using <digit> ::= <2>

Java BNF Identifier Example 2

<initial> <final> <final> <digit> using <digit> ::= <2>
<initial> <final> <final> <final> using <final> ::= <digit>
<initial> <more> <final> <final> using <more> ::= <final>
<initial> <more> <final> using <more> ::= <more> <final>
<initial> <more> using <more> ::= <more> <final>
<identifier> using <identifier> ::= <initial> <more>

EBNF Rules for Java Identifiers

- There is an extended BNF notation (EBNF) in which the meta-characters {} can be used to denote “zero or more”.
- In EBNF, the productions:

  <identifier> ::= <initial> | <initial> <more>

  <more> ::= <final> | <more> <final>

are replaced by the simpler production:

  <identifier> ::= <initial> { <final> }

- The set of meta-characters [] are used to enclose optional entries in EBNF.

Some uses for Identifiers

- All class names are identifiers:
  String, *Date*, *PrintStream* …
- All message names are identifiers:
  toUpperCase, *trim*, *println* …
- All variable names are identifiers:
  aString, *todaysDate*, *out* …
- Literal booleans are identifiers: *true*, *false*
- Other literals are not identifiers:
  “Fred”, 3, ‘S’ 43.2f

Java Identifier Conventions

- Class names start with an upper case letter.
- Message names start with a lower case letter.
- If an identifier consists of more than one word then the first letter of subsequent words is capitalized:
  - PrintStream ← class identifier
  - toUpperCase ← message identifier

Outline of Lecture 6

- Program errors
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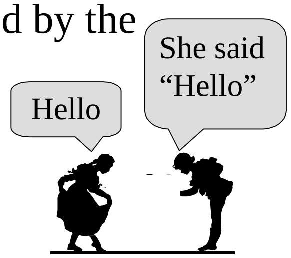
Literal Tokens

- In general, a **literal** is a token recognized by the compiler that is immediately translated into a language value or object.
- Common literals in programming languages include: characters, numbers and strings.
- The rules for forming literals varies from programming language to programming language.

Java String Literals

- In Java, a String literal is defined by the lexical rule:
  - – starts with a “
  - – zero or more characters
  - – ends with a “



- How do I add double quotes in a string?
- The \ character is called an escape character and is used to embed special symbols in a string.

Java String Literal Examples

“Hello.”

“Hello again!”

~~“She said ”Hello”.”~~

“She said \”Hello\”.”

“This is a tab character: \t”

“This is a newline character: \n”

Outline of Lecture 6

- Program errors
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Semantics

- Correct syntax is not enough to ensure that the **semantics** (meaning) of a program are correct.
- For example, both of these sentences have correct syntax according to the simple English grammar:

John read the blue book.

Book read the blue John.

- The first sentence makes sense semantically, while the second does not.

Semantic Errors

- Compilers do not find **semantic errors**.
- For example, we could write a syntactically correct program that displays the string “Goodbye”, but it would be semantically incorrect if we intended to display the string “Hello”.
- Another simple kind of semantic error is to put program statements in the wrong order.

You want this

```
   *
  * *
 *   *
******
```

```
******
*    *
 * *
  *
```

But you get this

Objectives of Lecture 7

Simple Java Programs

- Learn syntax rules for simple java statements.
- Translate the computation diagrams into Java statements and look at the output.

Outline of Lecture 7

- Statement syntax
- Variable declaration and reference syntax
- Packages and imports
- Message expression and assignment syntax
- Translation of diagrams to programs

Java Statement Syntax

- There are many different kinds of statements in Java, each terminated by a semi-colon.
- Four of the simplest kinds of statements are variable declarations, imports, message expressions, and assignments:

<statement> ::= <var dec>; | <import>; |

<message exp>; | <assign>; | …

- We will use all four kinds of statements in our simple programs.

Outline of Lecture 7

- Statement syntax
- Variable declaration and reference syntax
- Packages and imports
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- Translation of diagrams to programs

Variable Declarations

- Every Java variable must be declared.
- The syntax for each kind of variable declaration is different. (static, local, parameter, and instance variable)
- In this lecture, we will ignore instance variable declarations and method parameter declarations since we are not going to use them yet.
- A common approach is to declare each variable using its own declaration statement.

Static Variable Declarations

- Static variables:

<stat var dec> ::= <visibility> static [final] <class id> <var id>

<visibility> ::= public | private

- If the keyword final is included, the variable is actually a constant.
- For example, there is a public variable exported from class System that is bound to the screen and declared by:

public static final PrintStream out;

Local Variable Declarations

- Local variables:

  <local var dec> ::= [final] <class id> <var id>
- If the keyword final is included, the variable is actually a constant.
- For example, we declare local String and Date variables and a local Date constant:

  String myString;

  Date aDate;

  final Date birthDate;

Variable References

- Variables are used by writing variable references.
- A local variable reference is just the variable name (an identifier).

  <local var ref> ::= <id>
- A static variable reference is:

  <static var ref> ::= <export class> . <id>
- For example to refer to the screen object:

  System.out

Outline of Lecture 7

- Statement syntax
- Variable declaration and reference syntax
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Packages

- Classes that are put in Java libraries can be grouped together into **packages**.
- There are many standard Java packages.
- For example, the classes *Date* and *Stack* are defined in the package named **java.util**.
- For example, the class *Graphics* is defined in the package named **java.awt**.
- Awt stands for **Abstract Windowing Toolkit**.

Import Statements

- An **import** statement must be used to access the classes in a package.
- You can import one class from a package:

  import java.util.Date;
- You can import all classes from a package:

  import java.util.;*
- One package: **java.lang** is implicitly imported into all Java programs.
- *String* and *System* are two classes in the **java.lang** package.

Static Variable Shortcut

- If a static variable is used inside its exporting class, you can omit the exporting class.
- For example, inside the System class, the screen object can be referenced by:

  out

Outline of Lecture 7

- Statement syntax
- Variable declaration and reference syntax
- Packages and imports
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- Translation of diagrams to programs

Message Expression Syntax

- The syntax of a message expression is:

  <message exp> ::= <obj ref> . <message name> <args>
- A Java argument list is zero or more object references, separated by commas:

  <args> ::= () | ({<object ref>, } <object ref>)
- Since String literals are object references, two example message expressions are:

```
"Hello".toUpperCase();              ➔ "HELLO"
"Fred".concat(" Flintstone");       ➔"Fred Flintstone"
"Flintstone".substring(5, 9);       ➔"stone"
```

Message Expression Syntax

- Since variable references are also object references, another example of a message expression is:

  static variable object reference

  System.out.println(“Hello”);
- A message expression that returns an object is also an object reference so here is another valid message expression:

  System.out.println(“Fred”.concat(“ Flintstone”));

Assignment Statements

- An assignment is used to bind a variable to an object :

  <assign> ::= <var ref> = <obj ref>
- For example:

  String friend;

  String fullName;

  friend = "Fred";

  fullName = friend.concat(" Flintstone");

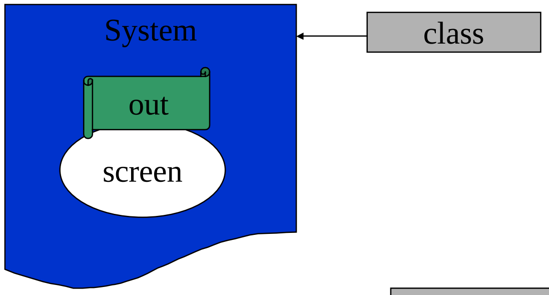
Outline of Lecture 7

- Statement syntax
- Variable declaration and reference syntax
- Packages and imports
- Message expression and assignment syntax
- Translation of diagrams to programs

Computation Diagrams → Java

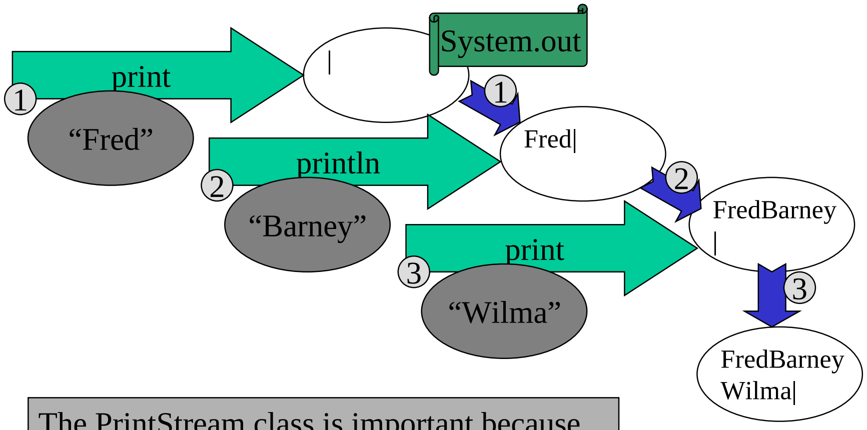
- Finally, we can translate all of our computation diagrams to Java programs.
- We will change the order that we translate the diagrams and sometimes we will combine several diagrams into a single program.
- We are still ignoring the program template itself and just concentrating on the statements it contains.

Public Static Variables - *out*



out is actually a constant.

PrintStream - Example



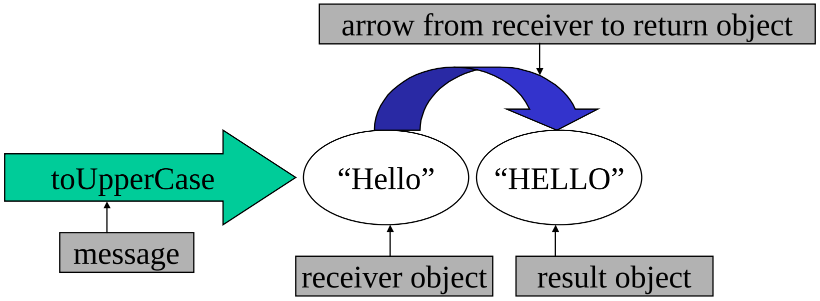
The PrintStream class is important because the screen is an instance of PrintStream.

Java - print & println

```
public class Snippet {
/*
   Experimenting with Java
*/
   public static void main(String args[]) {
   /* Program statements go here. */
         System.out.print(“Fred”);
         System.out.println(“Barney”);
         System.out.print(“Wilma”);
   }
}
```

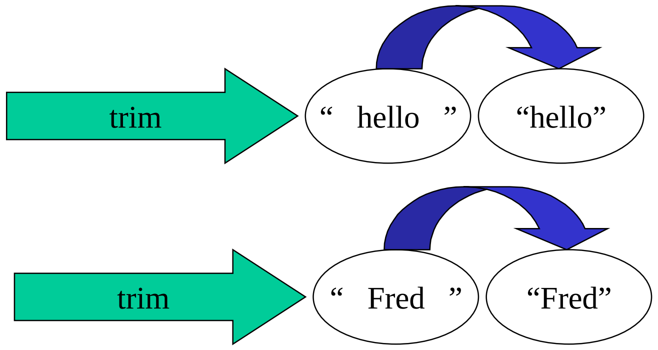
```
FredBarney
Wilma|
```

String Example - toUpperCase



A message that returns a result object

String Example - trim



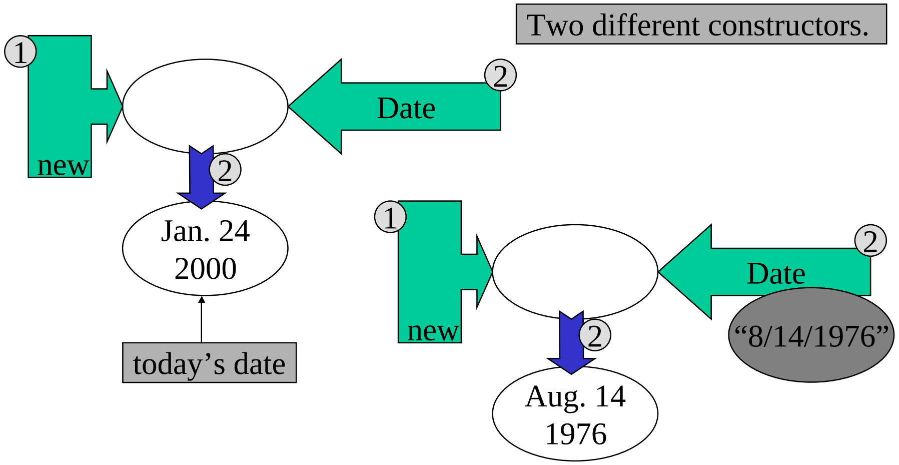
Different instances of the same class can respond differently because they have different state.

Java - toUpperCase & trim

```
public class Snippet {
/*
   Experimenting with Java
*/
   public static void main(String args[]) {
   /* Program statements go here. */
        System.out.println(“Hello”.toUpperCase());
        System.out.print(“   Hello   “.trim());
        System.out.println(“   Fred   “.trim());
   }
}
```

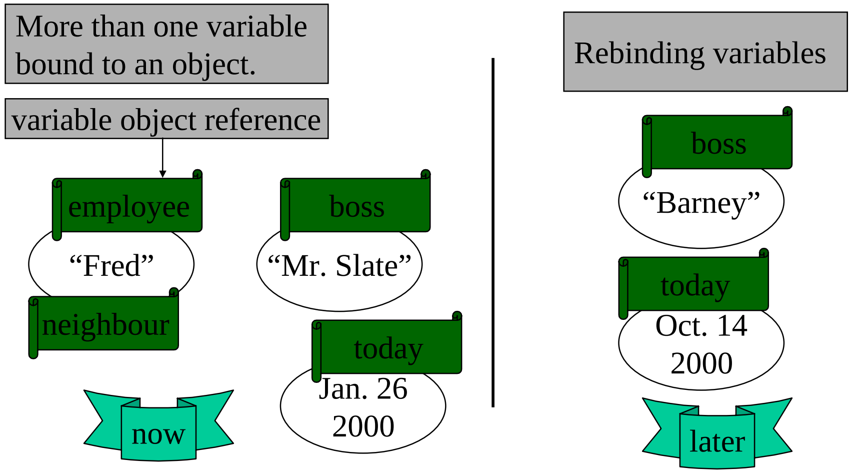
```
HELLO
HelloFred
|
```

Object Creation - Date



Two different constructors.

Variable Object References - Example

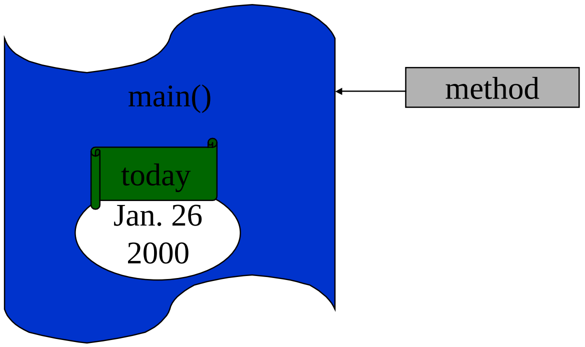


More than one variable bound to an object.

variable object reference

Rebinding variables

Local Variables - Example



Java - Creation & Variables 1

required to use the Date class

```
import java.util.*;
public class Snippet {
/*
   Experimenting with Java
*/
   public static void main(String args[]) {
   /* Program statements go here. */
        String  employee;
        String  neighbour;
        String  boss;
        Date    today;
```

Java - Creation & Variables 2

```
employee = "Fred";
neighbour = "Fred";
boss = "Mr. Slate";
today = new Date();
System.out.println(employee);
System.out.println(neighbour);
System.out.println(boss);
System.out.println(today);
```

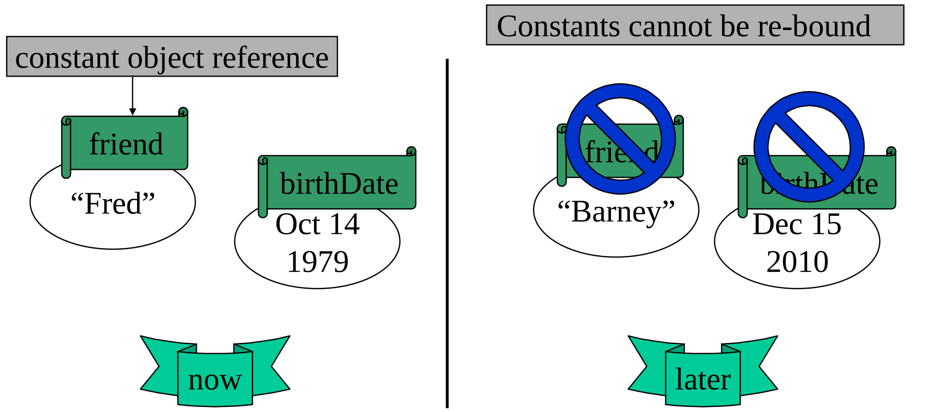
```
Fred
Fred
Mr. Slate
Mon Jan 24 12:06:47 MDT 2000
```

Java - Creation & Variables 3

```
        boss = "Barney";
        today = new Date("10/14/1999");
        System.out.println(boss);
        System.out.println(today);
   }
}
```

```
Barney
Thu Oct 14 00:00:00 MDT 1999
```

Constant Object References - Example



Java - Constants

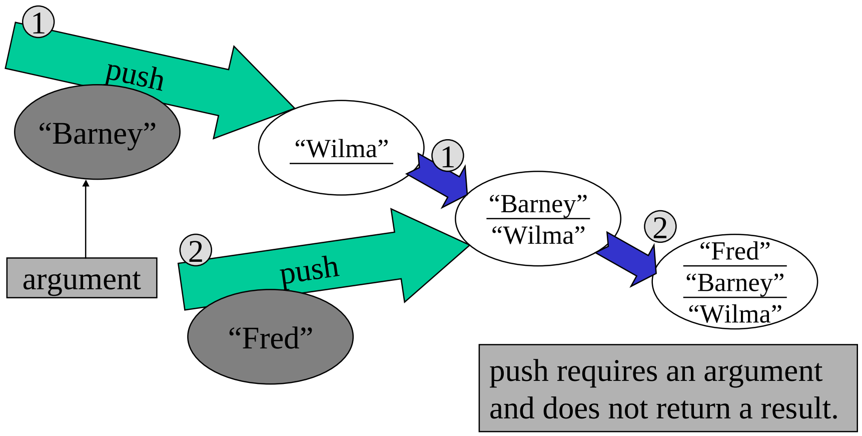
```
import java.util.*;
public class Snippet {
/* Experimenting with Java */
    public static void main(String args[]) {
    /* Program statements go here. */
            final String friend;
            final Date birthDate;
            friend = "Fred";
            birthDate = new Date();
            friend = "Barney";
            birthDate = new Date("12/15/2010");
    }
}
```

Java - Constants - Errors

```
Error   : Can't assign a second value to a blank final variable: friend
Snippet.java line 10     friend = "Barney";

Error   : Can't assign a second value to a blank final variable: birthDate
Snippet.java line 11     birthDate = new Date("12/15/2010");
```

Stack Example - push



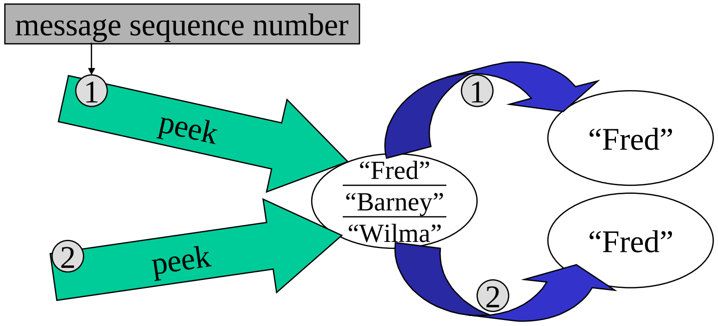
push requires an argument and does not return a result.

Java - push

```
import java.util.*;
public class Snippet {
/* Experimenting with Java */
   public static void main(String args[]) {
   /* Program statements go here. */
        Stack   aStack;
        aStack = new Stack();
        System.out.println(aStack);
        aStack.push("Wilma");
        System.out.println(aStack);
        aStack.push("Barney");
        System.out.println(aStack);
        aStack.push("Fred");
        System.out.println(aStack);
```

```
[]
[Wilma]
[Wilma, Barney]
[Wilma, Barney, Fred]
```

Stack Example - peek



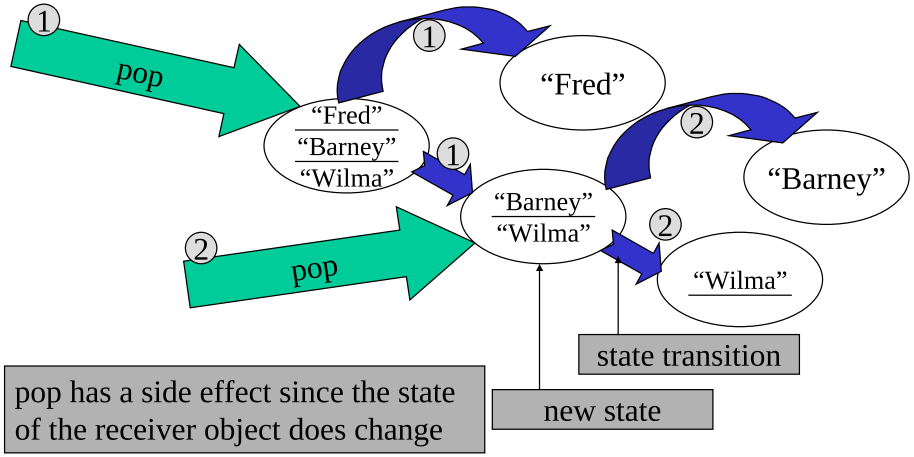
peek has no side effect since the state of the receiver object does not change

Java - peek

```
System.out.println(aStack);
System.out.println(aStack.peek());
System.out.println(aStack.peek());
System.out.println(aStack);
```

```
[Wilma, Barney, Fred]
Fred
Fred
[Wilma, Barney, Fred]
```

Stack Example - pop



pop has a side effect since the state of the receiver object does change

Java - pop

```
        System.out.println(aStack);
        System.out.println(aStack.pop());
        System.out.println(aStack);
        System.out.println(aStack.pop());
        System.out.println(aStack);
    }
}
```

```
[Wilma, Barney, Fred]
Fred
[Wilma, Barney]
Barney
[Wilma]
```

Objectives of Lecture 8

Keyboard Input and the Adventure Program

- Learn about using new classes.
- Understand the process behind the input of data.
- Write the first version of our Adventure program.

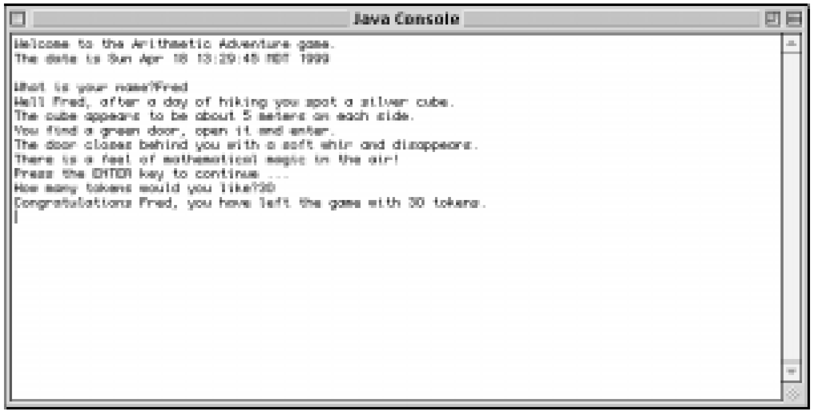
Outline of Lecture 8

- Demonstration of the final Adventure Program (Version 8)
- Algorithms
- The Keyboard Class
- Program Adventure (Version 1)
- Adding a local library to a project

Demonstration of Adventure 8

- Start Adventure Version 8.
- Play the game.

Adventure V1 Output



```
Welcome to the Arithmetic Adventure game.
The date is Sun Apr 18 13:29:45 MDT 1999

What is your name?Fred
Well Fred, after a day of hiking you spot a silver cube.
The cube appears to be about 5 meters on each side.
You find a green door, open it and enter.
The door closes behind you with a soft whir and disappears.
There is a feel of mathematical magic in the air!
Press the ENTER key to continue ...
How many tokens would you like?30
Congratulations Fred, you have left the game with 30 tokens.
```

Outline of Lecture 8

- Demonstration of the final Adventure Program (Version 8)
- Algorithms
- The Keyboard Class
- Program Adventure (Version 1)
- Adding a local library to a project

Algorithms

- If our problem is more complex than sending a few messages, we must decompose the problem into small steps.
- An **algorithm** is a finite collection of steps, performed in a prescribed order that terminates and yields a correct solution to a problem.
- For now, we will look at algorithms that consist of a simple series of consecutive steps.
- Later in the course, we will study algorithms that perform steps conditionally and repeat steps.

An Algorithm for Adventure 1

- For example, in Version 1 of the Adventure program, the steps are:
  - greet the user and prompt the user for a name
  - input the user name and bind a local variable to it
  - describe the game environment using the name
  - pause
  - prompt the user for a number of tokens
  - input a number of tokens and bind a local variable to it
  - say farewell to the user by name and indicate the number of tokens acquired during the game

New Computations

- We can implement the algorithm by putting a sequence of message expression statements and assignment statements into our program template.
- There are four new computations we need to perform:
  - input a String from the keyboard
  - input an Integer from the keyboard
  - pause until the user presses the ENTER key
  - output an Integer to the screen

Outline of Lecture 8

- Demonstration of the final Adventure Program (Version 8)
- Algorithms
- The Keyboard Class
- Program Adventure (Version 1)
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The *in* Variable

- The System class has a public reference to the screen object: *System.out*
- Unfortunately, there is no public reference to a keyboard object in the standard Java class libraries.
- We have created a library class called Keyboard that contains a public variable called ***in.***
- Note that the declared class of the ***in*** variable is Keyboard and that the exporting class is also Keyboard.

The Keyboard Class

- The Keyboard class is part of a local library called **UofAC114**.
- It declares the public variable `in` with declared class Keyboard, and includes messages:
  - pause
  - readString
  - readInteger
  - readFloat
- To use the Keyboard class, you need to know its protocol.

Keyboard Protocol

```
public class Keyboard {
/*
    An instance of this class represents a keyboard device that can be used
    to obtain input from the user.
*/

/* Public Variables */
    public final static Keyboard in;

/* Instance Methods */
    public void pause();
    /*
        Display a message and wait until the enter key is pressed.
    */
```

Keyboard Protocol (cont 2)

```
    public String readString();
    /*
        Answer a String that contains all of the characters
        typed by the user until the enter key is pressed.
    */

    public Integer readInteger();
    /*
        Answer an Integer that is represented by the String
        that contains all of the characters typed by the
        user until the enter key is pressed. If the text
        does not form a valid Integer, then answer null.
    */
}
```

Keyboard Protocol (cont 3)

```
    public Float readFloat() {
    /*
        Answer a Float that is represented by the String
        that contains all of the characters typed by the
        user until the enter key is pressed. If the text
        does not form a valid Integer, then answer null.
    */
}
```

Outputting an Integer

- The declared class of the public variable *out* is *PrintStream*.
- The protocol for *PrintStream* has many messages including *print(String)* and *print(Object)*.
- We can use *print(Object)* to print an Integer.

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Program - Adventure 1.1

```
import java.util.*;

public class Adventure {
/* Version 1
   This program is an arithmetic adventure game where an adventurer
   navigates rooms that contain treasure chests that are opened by
   correctly answering arithmetic problems.
*/
   public static void main(String args[]) {
   /* Program statements go here. */
         String  name;
         Integer tokens;
```

Program - Adventure 1.2

```
System.out.println("Welcome to the Arithmetic Adventure game.");
System.out.print("The date is ");
System.out.println(new Date());
System.out.println();
System.out.print("What is your name?");
name = Keyboard.in.readString();
System.out.print("Well ");
System.out.print(name);
System.out.println(", after a day of hiking you spot a silver cube.");
System.out.println("The cube appears to be about 5 meters on each side.");
System.out.println("You find a green door, open it and enter.");
System.out.println("The door closes behind you with a soft whir and disappears.");
System.out.println("There is a feel of mathematical magic in the air.");
```

Program - Adventure 1.3

```
         Keyboard.in.pause();
         System.out.print("How many tokens would you like?");
         tokens = Keyboard.in.readInteger();
         System.out.print("Congratulations ");
         System.out.print(name);
         System.out.print(", you have left the game with ");
         System.out.print(tokens);
         System.out.println(" tokens.");
         }
}
```

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Demonstration Adventure 1

- Open Adventure 1 in CodeWarrior
- Show how to add **C114UofA.jar** into the classes folder.
- Run.