This recitation

- An interesting point about A2: Using previous methods to avoid work in programming and debugging. How much time did *you* spend writing and debugging prepend?
- Enums (enumerations)
- Generics and Java's Collection interfaces and classes
- Parsing arithmetic expressions using a grammar that gives precedence to * and / over + and – (if there is time)

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How to use previous methods in A2

The A2 handout contained this:

Further guidelines and instructions!
"Note that some methods that you have to write …. Also, in writing methods 4..7, writing them in terms of calls on previously written methods may save you time."

Did you read that? Think about it? Attempt it?

A lesson in:
1. Reading carefully, wisely.
2. Thinking about what methods do, visualizing what they do.

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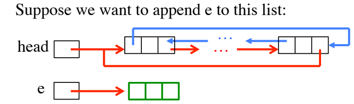
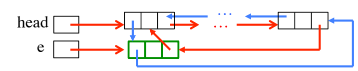
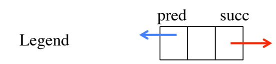
Suppose we want to append e to this list:



This is what it looks like after the append:



What if we prepended e instead of appending it?



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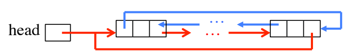
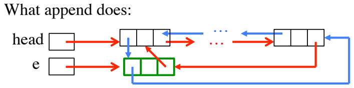
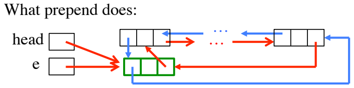


What append does:



What prepend does:



Therefore: prepend(v); can be done by

append(v); head= head.pred; body of prepend

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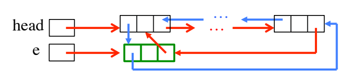
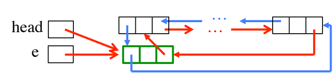
What append does



What prepend does



prepend(v) is simply append(v); head= head.pred;

How much time did you spend writing and debugging prepend?

Did you try to write prepend in terms of append?

Morals of the story:
1. Read carefully.
2. Visualize what methods do; understand specs completely.
3. Avoid duplication of effort by using previously written methods

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About enums (enumerations)

An enum: a class that lets you create mnemonic names for entities instead of having to use constants like 1, 2, 3, 4

The declaration below declares a class Suit.
After that, in any method, use Suit.Clubs, Suit.Diamonds, etc. as constants.

public enum Suit {Clubs, Diamonds, Hearts, Spades}

could be private, or any access modifier

new keyword

The constants of the class are Clubs, Diamonds, Hearts, Spades

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Four static final variables that contain pointers to objects

public enum Suit {Clubs, Diamonds, Hearts, Spades}

Clubs Suit@0

Diamonds Suit@1

Hearts Suit@2

Spades Suit@3

Suit@0 Suit

Suit@1 Suit

Suit@2 Suit

Suit@3 Suit

Clubs, Diamonds, Hearts, Spades
Are static variables of class enum

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Testing for an enum constant

public enum Suit {Clubs, Diamonds, Hearts, Spades}

Suit s= Suit.Clubs;
Then
s == Suit.Clubs is true s == Suit.Hearts is false

```
switch(s) {
   case Clubs:
   case Spades:
      color= "black"; break;
   case Diamonds:
   case Hearts:
      color= "red"; break;
}
```

Can use a switch statement

Type of s is Suit.

Inside the switch, you cannot write Suit.Hearts instead of Hearts

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Miscellaneous points about enums

public enum Suit {Clubs, Diamonds, Hearts, Spades}

This declaration is shorthand for a class that has a constructor, four constants (public static final variables), a static method, and some other components. Here are some points:

1. Suit is a subclass of Enum (in package java.lang)

2. It is not possible to create instances of class Suit, because its constructor is private!

3. It's as if Clubs (as well as the other three names) is declared within class Suit as

public static final Suit Clubs= **new** Suit(some values);

You don't care what values

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Miscellaneous points about enums

public enum Suit {Clubs, Diamonds, Hearts, Spades}

4. Static function values() returns a Suit[] containing the four constants. You can, for example, use it to print all of them:

```
for (Suit s : Suit.values())
    System.out.println(s);
```

toString in object Clubs returns the string "Clubs"

Output:
Clubs
Diamonds
Hearts
Spades

Can save this array in a static variable and use it over and over:

private static Suit[] mine= Suit.values();

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Miscellaneous points about enums

public enum Suit {Clubs, Diamonds, Hearts, Spades}

5. Static function valueOf(String name) returns the enum constant with that name:

Suit c= Suit.valueOf("Hearts");

After the assignment, c contains (the name of) object Hearts

c Suit@2

This is the object for Hearts:

Suit@2 Suit

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Miscellaneous points about enums

public enum Suit {Clubs, Diamonds, Hearts, Spades}

This declaration is shorthand for a class that has a constructor, four constants (public static final variables), a static method, and some other components. Here are some points:

6. Object Clubs (and the other three) has a function ordinal() that returns it position in the list

Suit.Clubs.ordinal() is 0
Suit.Diamonds.ordinal() is 1

We have only touched the surface of enums. E.g. in an enum declaration, you can write a private constructor, and instead of Clubs you can put a more elaborate structure. All this is outside the scope of CS2110.

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Package java.util has a bunch of classes called the Collection Classes that make it easy to maintain sets of values, list of values, queues, and so on. You should spend some time looking at their API specifications and getting familiar with them.

Remember:
A set is a bunch of distinct (different) values. No ordering is implied
A list is an ordered bunch of values. It may have duplicates.

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Interface Collection: abstract methods for dealing with a group of objects (e.g. sets, lists)

Abstract class AbstractCollection: overrides some abstract methods with methods to make it easier to fully implement Collection

AbstractList, AbstractQueue, AbstractSet, AbstractDeque overrides some abstract methods of AbstractCollection with real methods to make it easier to fully implement lists, queues, set, and deques

Next slide contains classes that you should become familiar with and use. Spend time looking at their specifications. There are also other useful Collection classes

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Class ArrayList extends AbstractList: An object is a growable/shrinkable list of values implemented in an array

Class HashSet extends AbstractSet: An object maintains a growable/shrinkable set of values using a technique called *hashing*. We will learn about hashing later.

Class LinkedList extends AbstractSequentialList: An object maintains a list as a doubly linked list

Class Vector extends AbstractList: An object is a growable/shrinkable list of values implemented in an array. An old class from early Java

Class Stack extends Vector: An object maintains LIFO (last-in-first-out) stack of objects

Class Arrays: Has lots of static methods for dealing with arrays —searching, sorting, copying, etc.

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ArrayList

ArrayList v= **new** ArrayList ();

defined in package java.util

An object of class ArrayList contains a growable/shrinkable list of elements (of class Object). You can get the size of the list, add an object at the end, remove the last element, get element i, etc. More methods exist! Look at them!

ArrayList@x1

Object

Fields that contain a list of objects ($o_0, o_1, \ldots, o_{size()-1}$)

ArrayList

ArrayList () add(Object)
get(int) size()
remove(…) set(int, Object)
…

v ArrayList@x1

Vector

HashSet

HashSet s= **new** HashSet();

Don't ask what "hash" means. Just know that a Hash Set object maintains a set

An object of class HashSet contains a growable/shrinkable set of elements (of class Object). You can get the size of the set, add an object to the set, remove an object, etc. More methods exist! Look at them!

HashSet@y2

Object

Fields that contain a setof objects $\{o_0, o_1, \ldots, o_{size()-1}\}$

Hashset

HashSet() add(Object)
contains(Object) size()
remove(Object)
…

s HashSet@y2

HashSet

Iterating over a HashSet or ArrayList

HashSet s= **new** HashSet();

… code to store values in the set …

for (Object e : s) {
System.out.println(c);
}

A loop whose body is executed once with e being each element of the set. Don't know order in which set elements processed

Use same sort of loop to process elements of an ArrayList in the order in which they are in the ArrayList .

HashSet@y2

Object

Fields that contain a setof objects $\{o_0, o_1, \ldots, o_{size()-1}\}$

HashSet

HashSet() add(Object)
contains(Object) size()
remove(Object)
…

s HashSet@y2

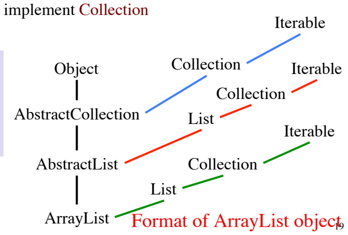
HashSet

Interface Collection: abstract methods for dealing with a group of objects (e.g. sets, lists)

Abstract class AbstractCollection: overrides some abstract methods with real methods to make it easier to fully implement Collection

Iterable Not discussed today

ArrayList implements 3 other interfaces, not shown



Format of ArrayList object

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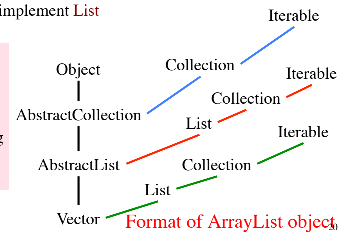
Interface List: abstract methods for dealing with a list of objects ($o_0, \ldots, o_{n-1}$). Examples: arrays, Vectors

Abstract class AbstractList: overrides some abstract methods with real methods to make it easier to fully implement List

Iterable Not discussed today

Homework: Look at API specifications and build diagram giving format of HashSet



Format of ArrayList object

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Generics and Java's Collection Classes

ge·ner·ic *adjective* \jə-ˈnerik, -rēk\
relating or applied to or descriptive of all members of a genus, species, class, or group: common to or characteristic of a whole group or class: typifying or subsuming: not specific or individual.

From Wikipedia: generic programming: a style of computer programming in which algorithms are written in terms of to-be-specified-later types that are then *instantiated* when needed for specific types provided as parameters.

Read carefully!

In Java: Without generics, every Vector object contains a list of elements of class Object. Clumsy

With generics, we can have a Vector of Strings, a Vector of Integers, a Vector of Genes. Simplifies programming, guards against some errors

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Generics: say we want an ArrayList of only one class

API specs: ArrayList declared like this:

public class ArrayList <E> **extends** AbstractList<E>
implements List<E> … { … }

Means:
Can create Vector specialized to certain class of objects:

ArrayList <String> vs= **new** ArrayList <String>(); //only Strings
ArrayList <Integer> vi= **new** ArrayList <Integer>(); //only Integers

vs.add(3);
vi.add("abc");
These are illegal

int n= vs.get(0).size();

vs.get(0) has type String
No need to cast

ArrayList to maintain list of Strings is cumbersome

ArrayList v= **new** ArrayList ();

… Store a bunch of Strings in v … —Only Strings, nothing else

// Get element 0, store its size in n

String ob= ((String) v.get(0)).length();
int n= ob.size();

All elements of v are of type Object. So, to get the size of element 0, you first have to cast it to String.

Make mistake, put an Integer in v? May not catch error for some time.

v ArrayList@x1

ArrayList @x1

Object

Fields that contain a list of objects ($o_0, o_1, \ldots, o_{size()-1}$) — ArrayList

Vector() add(Object)
get(int) size()
remove() set(int, Object)
…

ArrayList

Generics allow us to say we want Vector of Strings only

API specs: Vector declared like this:

public class Vector<E> **extends** AbstractList<E>
implements List<E> … { … }

Full understanding of generics is not given in this recitation. E.g. We do not show you how to write a generic class.

Important point: When you want to use a class that is defined like Vector above, you can write

Vector<C> v= **new** Vector<C>(…);

to have v contain a Vector object whose elements HAVE to be of class C, and when retrieving an element from v, its class is C.

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Parsing Arithmetic Expressions

Introduced in lecture briefly, to show use of grammars and recursion. Done more thoroughly and carefully here.

We show you a real grammar for arithmetic expressions with integer operands; operations +, -, *, /; and parentheses ( ). It gives precedence to multiplicative operations.

We write a recursive descent parser for the grammar and have it generate instructions for a stack machine (explained later). You learn about infix, postfix, and prefix expressions.

Historical note: Gries wrote the first text on compiler writing, in 1971. It was the first text written/printed on computer, using a simple formatting application. It was typed on punch cards. You can see the cards in the Stanford museum; visit infolab.stanford.edu/pub/voy/museum/pictures/display/floor5.htm

Parsing Arithmetic Expressions

-5 + 6   Arithmetic expr in infix notation
5 – 6 +   Same expr in postfix notation

infix: operation between operands
postfix: operation after operands
prefix: operation before operands

PUSH 5 NEG PUSH 6 ADD	Corresponding machine language for a "stack machine": PUSH: push value on stack NEG: negate the value on top of stack ADD: Remove top 2 stack elements, push their sum onto stack

Infix requires parentheses. Postfix doesn't

(5 + 6) * (4 – 3)   Infix
5 6 + 4 3 - *   Postfix

5 + 6 * 3   Infix
5 6 3 * +   Postfix

Math convention: * has precedence over +. This convention removes need for many parentheses

Task: Write a parser for conventional arithmetic expressions whose operands are ints.

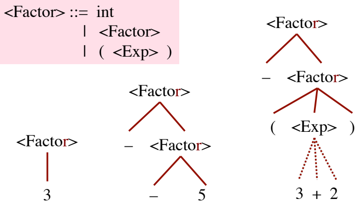
1. Need a grammar for expressions, which defines legal arith exps, giving precedence to * / over + -
2. Write recursive procedures, based on grammar, to parse the expression given in a String. Called a recursive descent parser

Use 3 syntactic categories: <Exp>, <Term>, <Factor> Grammar

A <Factor> has one of 3 forms:
1. integer
2. – <Factor>
3. (<Exp>)

Show "syntax trees" for
3   – – 5   – (3 + 2)

<Factor> ::= int
  | <Factor>
  | (<Exp>)



Haven't shown <Exp> grammar yet

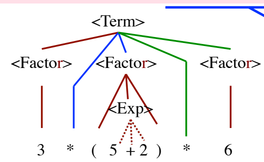
Use 3 syntactic categories: <Exp>, <Term>, <Factor> Grammar

A <Term> is:
 <Factor> followed by 0 or more occurs. of **multop** <Factor>
where **multop** is * or /

Means: 0 or 1 occurrences of * or /

<Term> ::= <Factor> { {* | /}1 <Factor> }

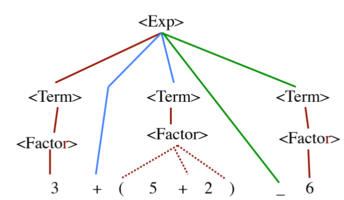
Means: 0 or more occurrences of thing inside { }



Use 3 syntactic categories: <Exp>, <Term>, <Factor> Grammar

A <Exp> is:
 <Term> followed by 0 or more occurrences of **addop** <Term>
where **addop** is + or -

<Exp> ::= <Term> { {+ | -}1 <Term> }



Class Scanner

Initialized to a String that contains an arithmetic expression.
Delivers the tokens in the String, one at a time

Expression: 3445*(20 + 16)
Tokens:
3445
*
(
20
+
16
)

All parsers use a scanner, so they do not have to deal with the input character by character and do not have to deal with whitespace

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Class Scanner

An instance provides tokens from a string, one at a time.
A token is either
1. an unsigned integer,
2. a Java identifier
3. an operator + - * / %
4. a paren of some sort: ( ) [ ] { }
5. any seq of non-whitespace chars not included in 1..4.

```
public Scanner(String s)          // An instance with input s
public boolean hasToken()         // true iff there is a token in input
public String token()             // first token in input (null if none)
public String scanOverToken()     // remove first token from input
                                  // and return it (null if none)
public boolean tokenIsInt()       // true iff first token in input is int
public boolean tokenIsId()        // true iff first token in input is a
                                  // Java identifier
```

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Parser for <Factor>

```
/** scanner's input should start with a <Factor>
        —if not, throw a RuntimeException.
   Return the postfix instructions for <Factor>
   and have scanner remove the <Factor> from its input.
  <Factor> ::= an integer
             |  – <Factor>
             |  ( <Expr> )      */
 public static String parseFactor(Scanner scanner)
```

The spec of every parser method for a grammatical entry is similar. It states
1. What is in the scanner when parsing method is called
2. What the method returns.
3. What was removed from the scanner during parsing.

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Parser for <Exp>

```
/** scanner's input should start with an <Exp>
        --if not throw a RuntimeException.
    Return corresponding postfix instructions
    and have scanner remove the <Exp> from its input.

    <Exp> := <Term> { {+ or -}1 <Term>}   */
  public static String parseExp(Scanner scanner) {
    String code= parseTerm(scanner);
    while ("+".equals(scanner.token()) ||
              "-".equals(scanner.token())) {
        String op= scanner.scanOverToken();
        String rightOp= parseTerm(scanner);
        code= code + rightOp +
               (op.equals("+") ? "PLUS\n" : "MINUS\n");
    }
    return code;
  }
```

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