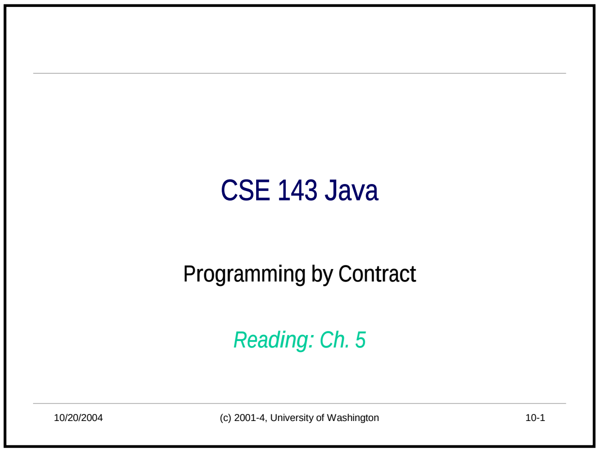
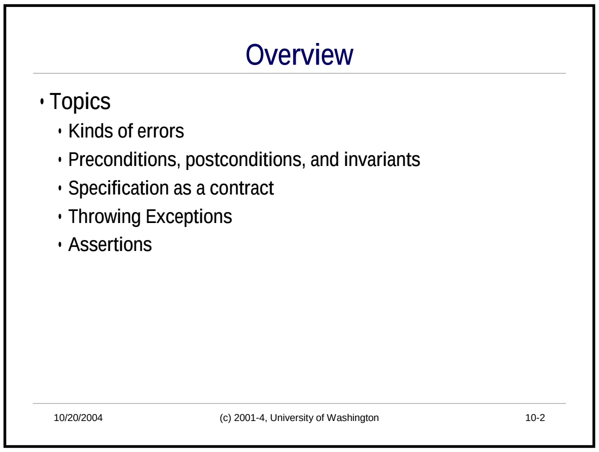


CSE 143 Java

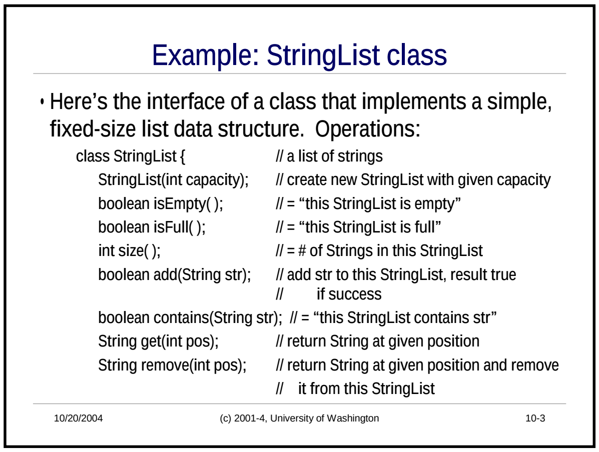
Programming by Contract

Reading: Ch. 5



Overview

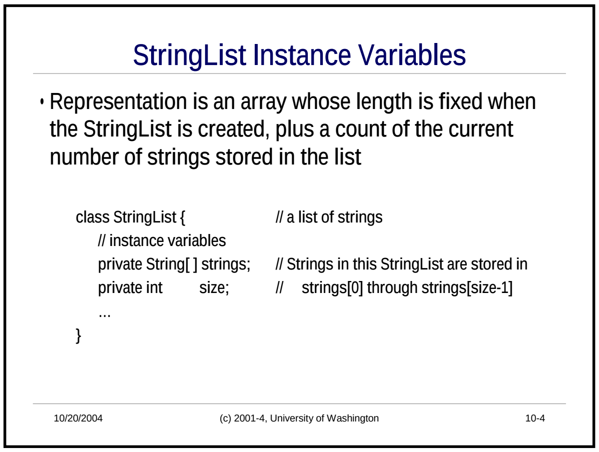
- Topics
  - Kinds of errors
  - Preconditions, postconditions, and invariants
  - Specification as a contract
  - Throwing Exceptions
  - Assertions



Example: StringList class

- Here's the interface of a class that implements a simple, fixed-size list data structure. Operations:

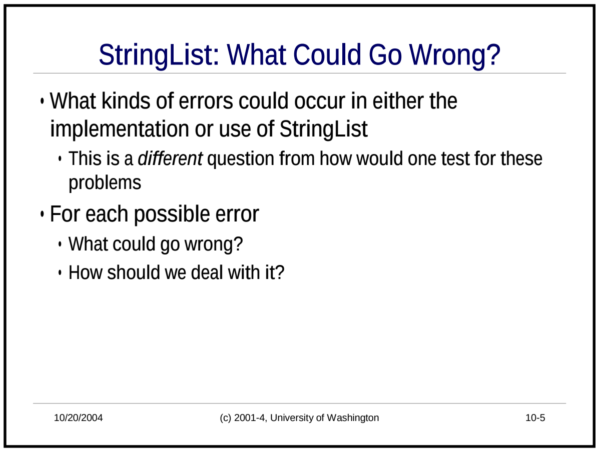
```
class StringList {                 // a list of strings
    StringList(int capacity);      // create new StringList with given capacity
    boolean isEmpty( );            // = "this StringList is empty"
    boolean isFull( );             // = "this StringList is full"
    int size( );                   // = # of Strings in this StringList
    boolean add(String str);       // add str to this StringList, result true
                                   //       if success
    boolean contains(String str);  // = "this StringList contains str"
    String get(int pos);           // return String at given position
    String remove(int pos);        // return String at given position and remove
                                   //    it from this StringList
```



StringList Instance Variables

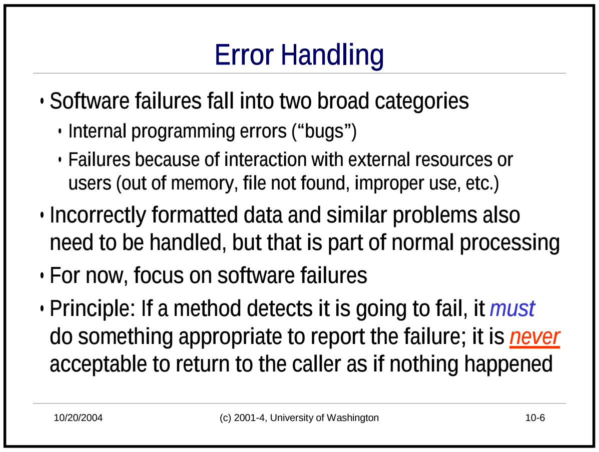
- Representation is an array whose length is fixed when the StringList is created, plus a count of the current number of strings stored in the list

```
class StringList {              // a list of strings
    // instance variables
    private String[ ] strings;  // Strings in this StringList are stored in
    private int       size;     //    strings[0] through strings[size-1]
    …
}
```



StringList: What Could Go Wrong?

- What kinds of errors could occur in either the implementation or use of StringList
  - This is a *different* question from how would one test for these problems
- For each possible error
  - What could go wrong?
  - How should we deal with it?



Error Handling

- Software failures fall into two broad categories
  - Internal programming errors ("bugs")
  - Failures because of interaction with external resources or users (out of memory, file not found, improper use, etc.)
- Incorrectly formatted data and similar problems also need to be handled, but that is part of normal processing
- For now, focus on software failures
- Principle: If a method detects it is going to fail, it *must* do something appropriate to report the failure; it is *never* acceptable to return to the caller as if nothing happened

Preconditions and Postconditions

- Methods typically make assumptions about the state of the world before, during, and after they are executed
  - Typically logical formulas: 0 <= size < capacity; the array is sorted a[0] <= a[1] <= … <= a[size-1]; etc.
- Two key kinds of assumptions
  - *Precondition*: Something that must be true before a method can be called; a requirement
  - *Postcondition*: Something that is guaranteed to be true after a method terminates execution (provided the precondition was true when it was called)

Preconditions & Postconditions

- What would be reasonable preconditions for

  a square root function?

  a method to insert new item into a list object?

- What would be reasonable postconditions for

  a sort routine?

  the constructor for a list object?

Class Invariants

- An invariant is a condition that should always be true at a particular place in a program
- Special case: a *class invariant* –an invariant about properties of class instances; often a relationship between instance variables (state)
  - Examples

    0 <= size <= capacity

    The list data is stored in items[0..size-1]
  - Note: a class invariant might be false for a time while a method is updating related variables, but it must *always* be true by the time a constructor or method terminates

Writing Bug-Free Software

- Preconditions, postconditions, and invariants are incredibly useful
- Include all non-trivial ones as comments in the code
  - These are essential parts of the design and a reader must understand them to understand the code
  - If you don’t write them down, the reader (who may be you) will have to reconstruct them as best he/she can
- Whenever you update a variable, check any invariants that refer to it to be sure the invariant still holds
  - May need to update related variables to make this happen

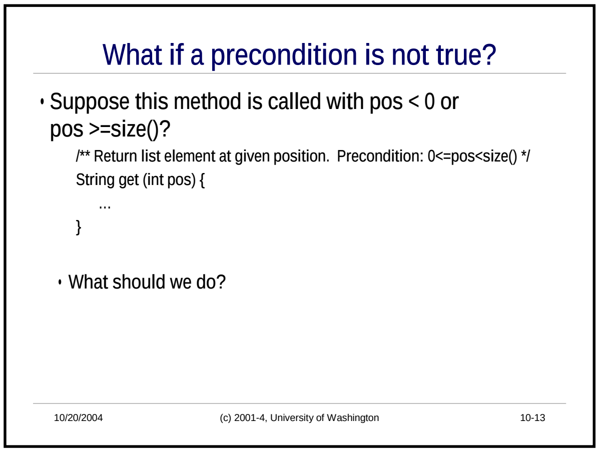
Design by Contract

- The preconditions and postconditions of a method can be viewed as a *contract* between the implementer of the method and the client code that uses it
- Clearly specifies the responsibilities of both parties
  - Client must ensure all preconditions are true before calling the method
  - Implementation must guarantee that postconditions are true, provided the preconditions were true when the method was called

    (assuming that adequate resources are available and other requirements are satisfied – see below)

Precondition Failures

- Principle: Crash early!
  - The sooner a precondition failure is detected the better
- Who is responsible for checking?
  - Most logical place is at the beginning of the called method

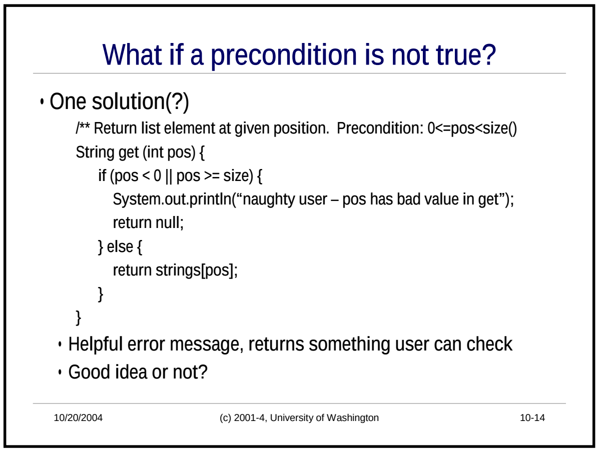


What if a precondition is not true?

- Suppose this method is called with pos < 0 or pos >=size()?

```
/** Return list element at given position.  Precondition: 0<=pos<size() */
String get (int pos) {
      …
}
```

  - What should we do?

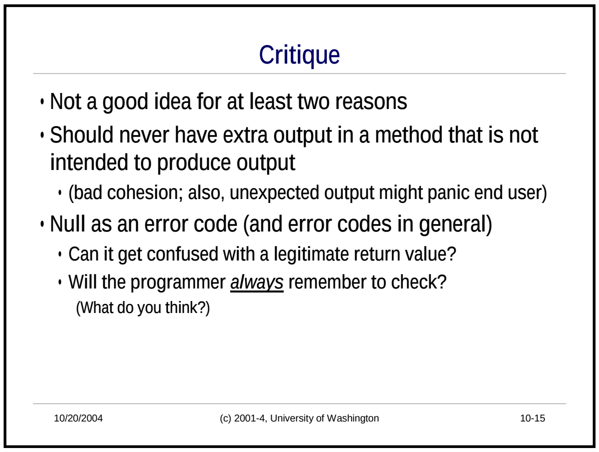


What if a precondition is not true?

- One solution(?)

```
/** Return list element at given position.  Precondition: 0<=pos<size()
String get (int pos) {
      if (pos < 0 || pos >= size) {
          System.out.println(“naughty user – pos has bad value in get”);
          return null;
      } else {
          return strings[pos];
      }
}
```

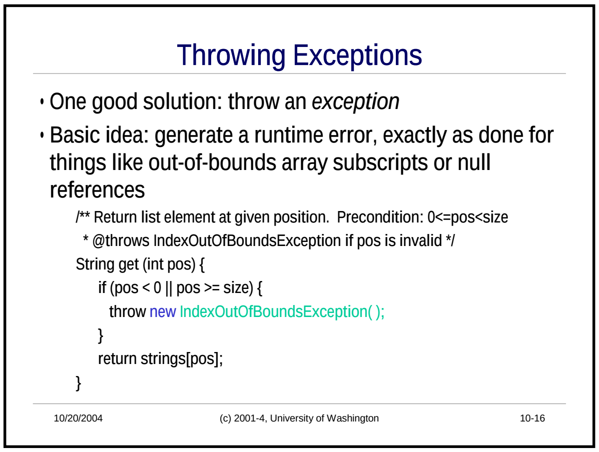
  - Helpful error message, returns something user can check
  - Good idea or not?



Critique

- Not a good idea for at least two reasons
- Should never have extra output in a method that is not intended to produce output
  - (bad cohesion; also, unexpected output might panic end user)
- Null as an error code (and error codes in general)
  - Can it get confused with a legitimate return value?
  - Will the programmer *always* remember to check?

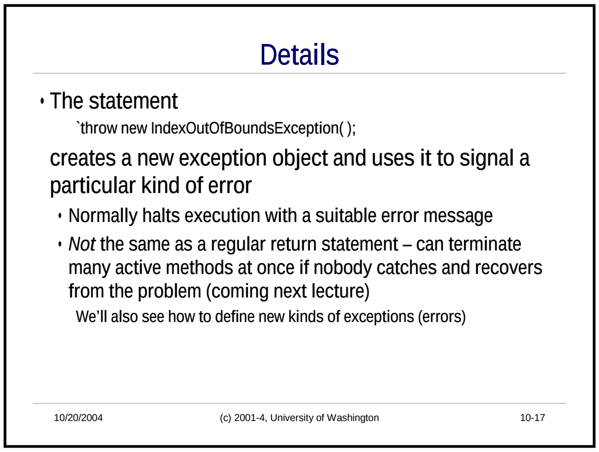
    (What do you think?)



Throwing Exceptions

- One good solution: throw an *exception*
- Basic idea: generate a runtime error, exactly as done for things like out-of-bounds array subscripts or null references

```
/** Return list element at given position.  Precondition: 0<=pos<size
  * @throws IndexOutOfBoundsException if pos is invalid */
String get (int pos) {
      if (pos < 0 || pos >= size) {
         throw new IndexOutOfBoundsException( );
      }
      return strings[pos];
}
```



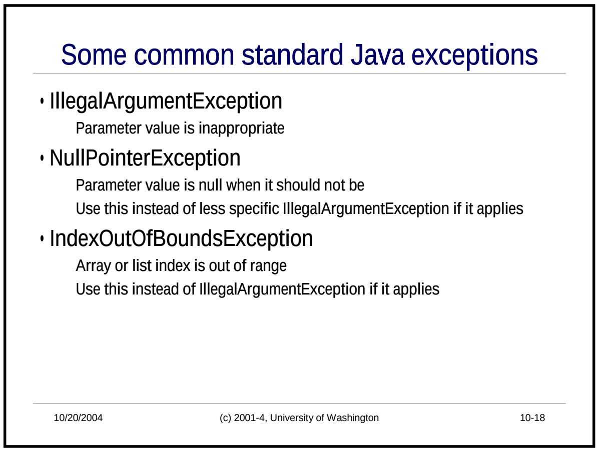
Details

- The statement

  `throw new IndexOutOfBoundsException( );

  creates a new exception object and uses it to signal a particular kind of error
  - Normally halts execution with a suitable error message
  - *Not* the same as a regular return statement – can terminate many active methods at once if nobody catches and recovers from the problem (coming next lecture)

    We’ll also see how to define new kinds of exceptions (errors)



Some common standard Java exceptions

- IllegalArgumentException

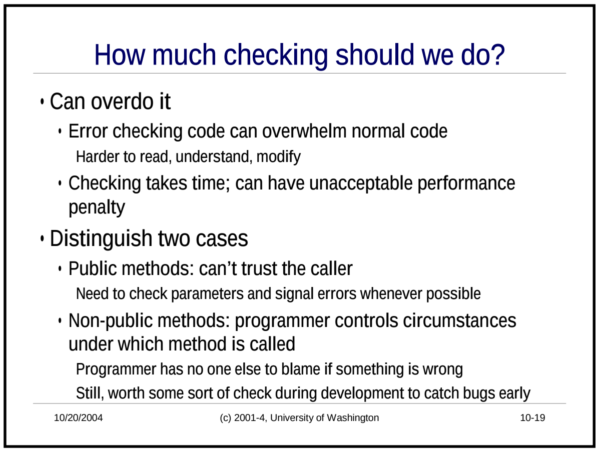
  Parameter value is inappropriate
- NullPointerException

  Parameter value is null when it should not be

  Use this instead of less specific IllegalArgumentException if it applies
- IndexOutOfBoundsException

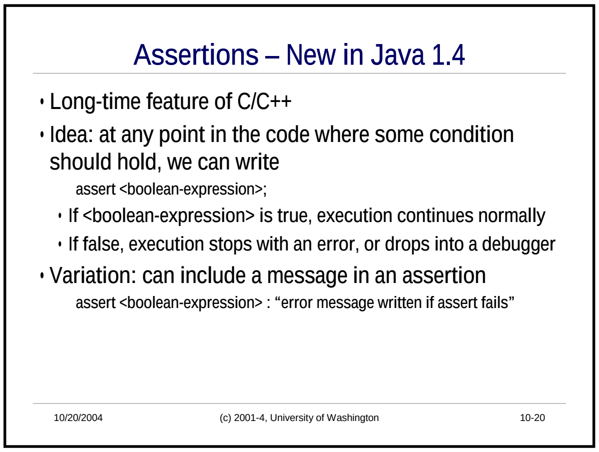
  Array or list index is out of range

  Use this instead of IllegalArgumentException if it applies



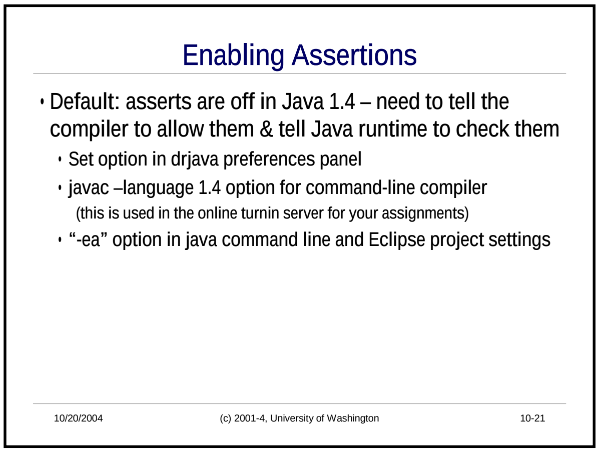
How much checking should we do?

- Can overdo it
  - Error checking code can overwhelm normal code
    - Harder to read, understand, modify
  - Checking takes time; can have unacceptable performance penalty
- Distinguish two cases
  - Public methods: can't trust the caller
    - Need to check parameters and signal errors whenever possible
  - Non-public methods: programmer controls circumstances under which method is called
    - Programmer has no one else to blame if something is wrong
    - Still, worth some sort of check during development to catch bugs early



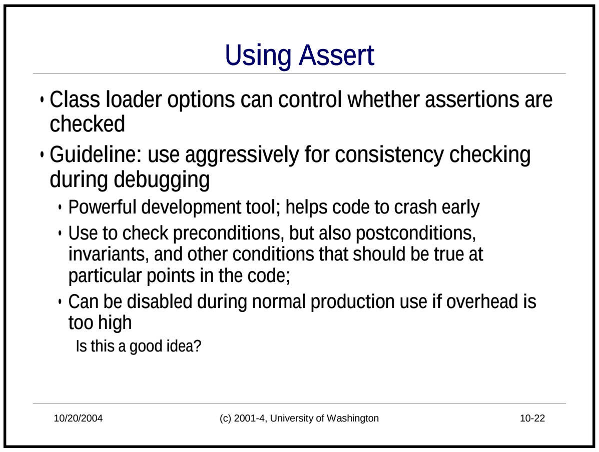
Assertions – New in Java 1.4

- Long-time feature of C/C++
- Idea: at any point in the code where some condition should hold, we can write
  - assert <boolean-expression>;
  - If <boolean-expression> is true, execution continues normally
  - If false, execution stops with an error, or drops into a debugger
- Variation: can include a message in an assertion
  - assert <boolean-expression> : "error message written if assert fails"



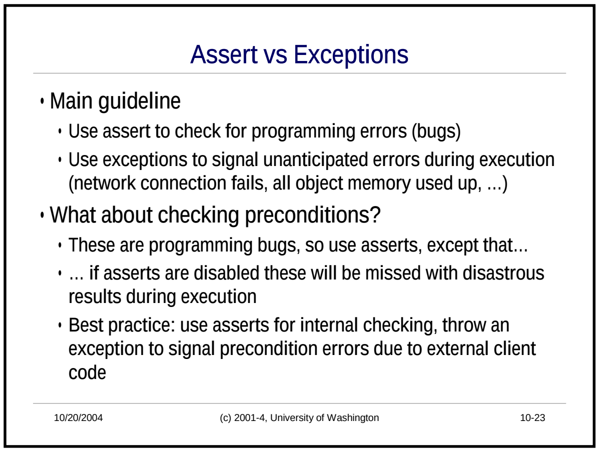
Enabling Assertions

- Default: asserts are off in Java 1.4 – need to tell the compiler to allow them & tell Java runtime to check them
  - Set option in drjava preferences panel
  - javac –language 1.4 option for command-line compiler
    - (this is used in the online turnin server for your assignments)
  - "-ea" option in java command line and Eclipse project settings



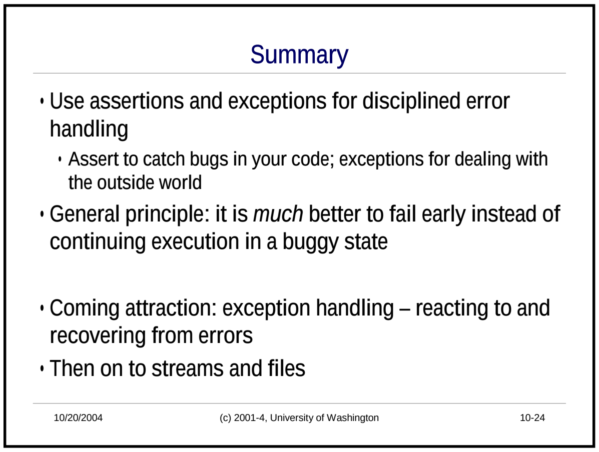
Using Assert

- Class loader options can control whether assertions are checked
- Guideline: use aggressively for consistency checking during debugging
  - Powerful development tool; helps code to crash early
  - Use to check preconditions, but also postconditions, invariants, and other conditions that should be true at particular points in the code;
  - Can be disabled during normal production use if overhead is too high
    - Is this a good idea?



Assert vs Exceptions

- Main guideline
  - Use assert to check for programming errors (bugs)
  - Use exceptions to signal unanticipated errors during execution (network connection fails, all object memory used up, ...)
- What about checking preconditions?
  - These are programming bugs, so use asserts, except that...
  - ... if asserts are disabled these will be missed with disastrous results during execution
  - Best practice: use asserts for internal checking, throw an exception to signal precondition errors due to external client code



Summary

- Use assertions and exceptions for disciplined error handling
  - Assert to catch bugs in your code; exceptions for dealing with the outside world
- General principle: it is *much* better to fail early instead of continuing execution in a buggy state

- Coming attraction: exception handling – reacting to and recovering from errors
- Then on to streams and files