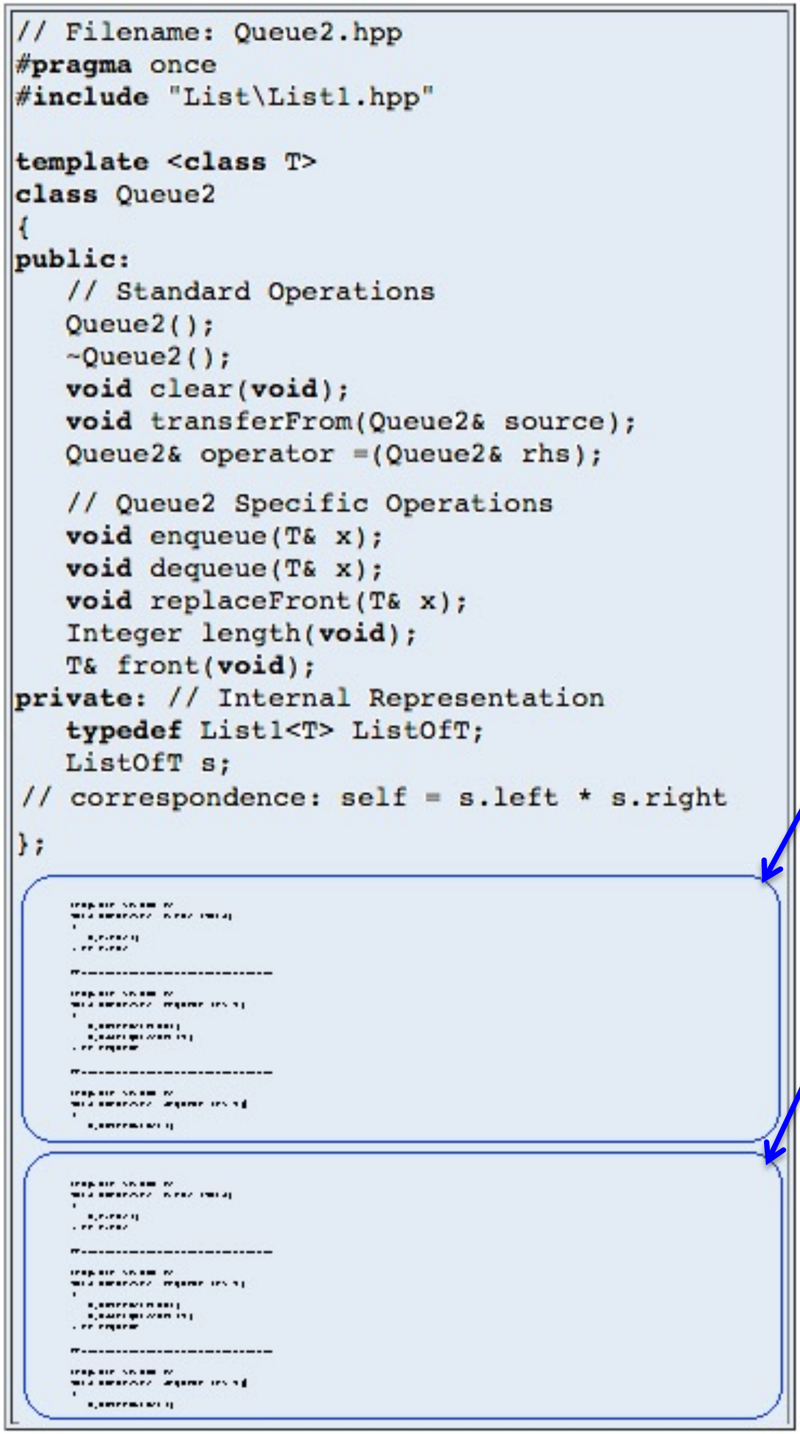
Member Function Implementations Of a Layered Component

Queue Layered on List
Implementation #1

Illustrating the *correspondence*

```
self = s.left * s.right
```



```
// Filename: Queue2.hpp
#pragma once
#include "List\List1.hpp"

template <class T>
class Queue2
{
public:
   // Standard Operations
   Queue2();
   ~Queue2();
   void clear(void);
   void transferFrom(Queue2& source);
   Queue2& operator =(Queue2& rhs);

   // Queue2 Specific Operations
   void enqueue(T& x);
   void dequeue(T& x);
   void replaceFront(T& x);
   Integer length(void);
   T& front(void);
private: // Internal Representation
   typedef List1<T> ListOfT;
   ListOfT s;
 // correspondence: self = s.left * s.right

};
```

Member Function Implementations

- Are placed at the bottom of the .hpp file

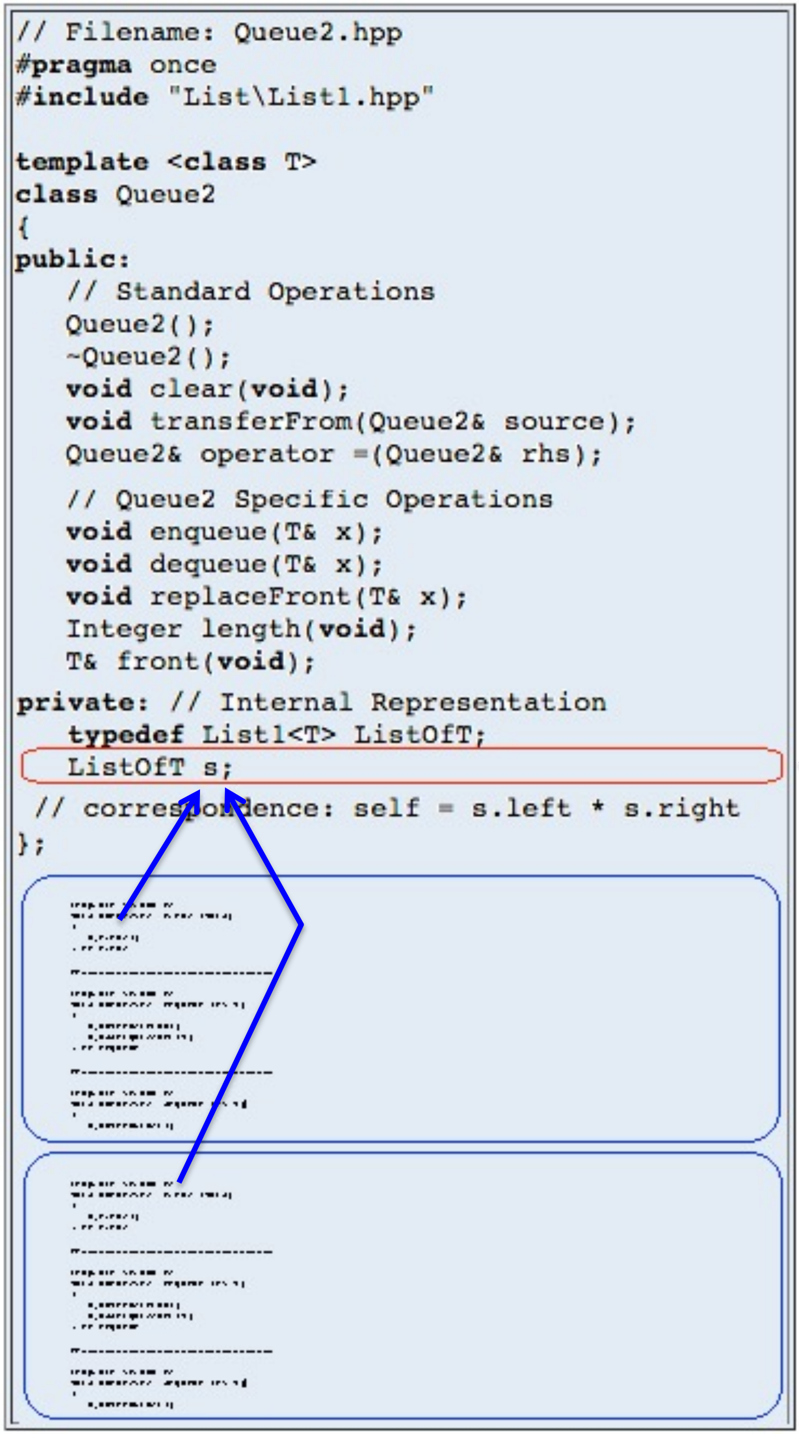
  There are two parts:

  1. Standard Operations Part

     The member functions that implement the 5 standard operations

  2. Component Specific Operations Part

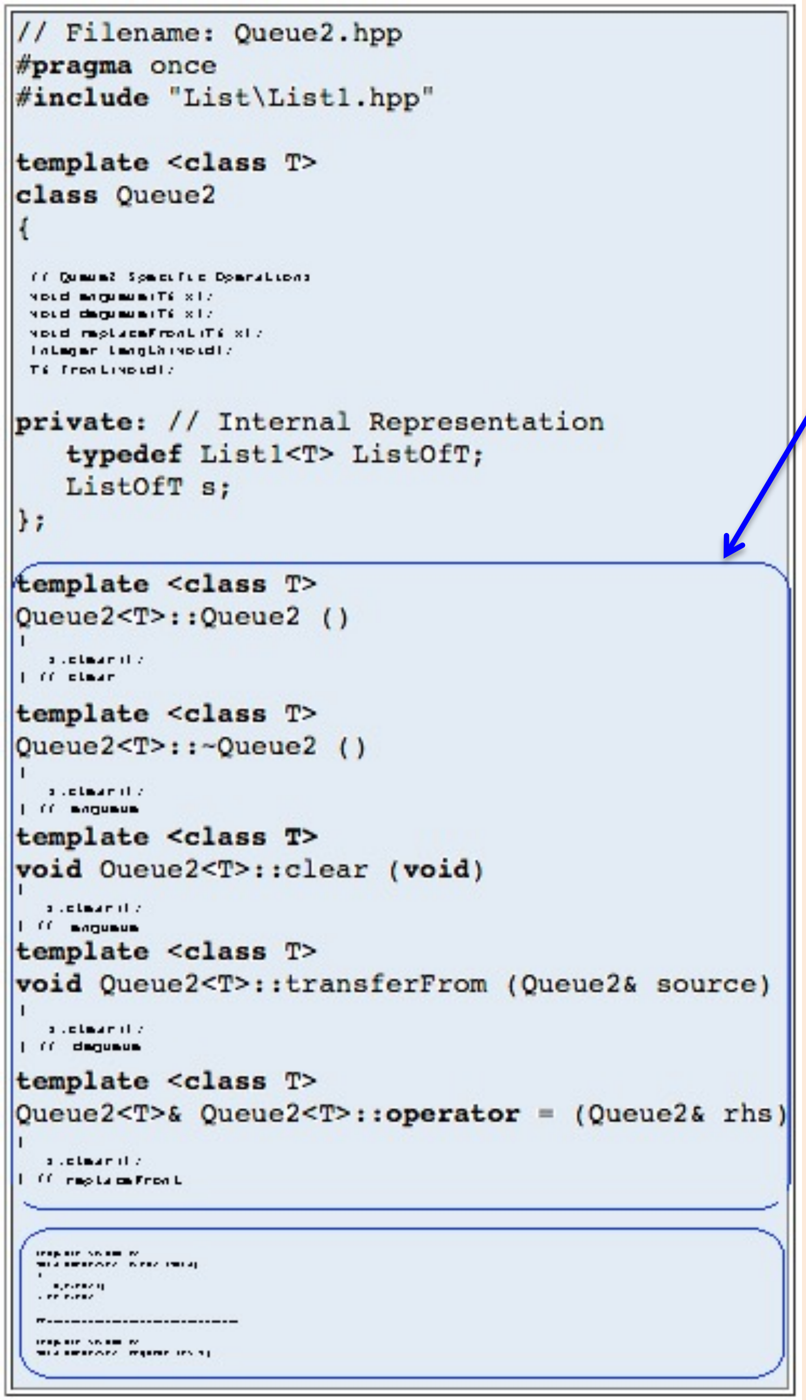
     The member functions that implement the component specific operations



```
// Filename: Queue2.hpp
#pragma once
#include "List\List1.hpp"

template <class T>
class Queue2
{
public:
   // Standard Operations
   Queue2();
   ~Queue2();
   void clear(void);
   void transferFrom(Queue2& source);
   Queue2& operator =(Queue2& rhs);

   // Queue2 Specific Operations
   void enqueue(T& x);
   void dequeue(T& x);
   void replaceFront(T& x);
   Integer length(void);
   T& front(void);
private: // Internal Representation
   typedef List1<T> ListOfT;
   ListOfT s;
 // correspondence: self = s.left * s.right
};
```

Member Function Implementations

- Recall: all member function implementations:
  - Work with the concrete internal representation
  - For this example using Queue, the member functions work with variable *s*, declared from ListOfT



```
// Filename: Queue2.hpp
#pragma once
#include "List\List1.hpp"

template <class T>
class Queue2
{

 // Queue2 Specific Operations
 void enqueue(T& x);
 void dequeue(T& x);
 void replaceFront(T& x);
 Integer length(void);
 T& front(void);

private: // Internal Representation
   typedef List1<T> ListOfT;
   ListOfT s;
};

template <class T>
Queue2<T>::Queue2 ()
{
   s.clear();
} // clear

template <class T>
Queue2<T>::~Queue2 ()
{
   s.clear();
} // enqueue
template <class T>
void Queue2<T>::clear (void)
{
   s.clear();
} // enqueue
template <class T>
void Queue2<T>::transferFrom (Queue2& source)
{
   s.clear();
} // dequeue

template <class T>
Queue2<T>& Queue2<T>::operator = (Queue2& rhs)
{
   s.clear();
} // replaceFront

[illegible]
[illegible]
[illegible]
   [illegible]
[illegible]

//--------------------------

[illegible]
[illegible]
```

Standard Operations Part

- The 5 Standard Operations are:

  1. Queue2 – the constructor

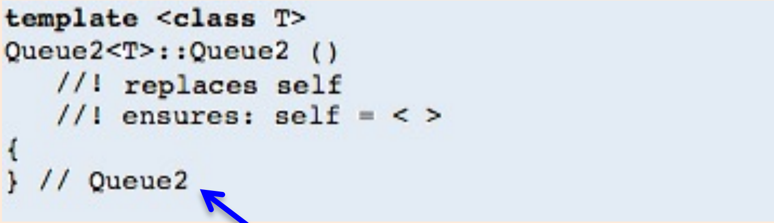
  2. ~Queue2 – the destructor

  3. transferFrom

  1. operator = – the assignment operator

  2. clear

The Constructor



```
template <class T>
Queue2<T>::Queue2 ()
   //! replaces self
   //! ensures: self = < >
{
} // Queue2
```

- Has the same name as the component
- The constructor’s code initializes the data members
- Data members declared from layered upon components, e.g., *s* declared from ListOfT:
  Are automatically initialized by their own constructors, the C++ compiler guarantees that these constructors will be called
- For Queue layered on List:
  - List’s constructor initializes *s* to:
    `s = (<>,<>)`
  - Recall the *correspondence*:
    `self = s.left * s.right`
  - So no code is required for Queue’s constructor, because the ensures clause for Queue’s constructor is:

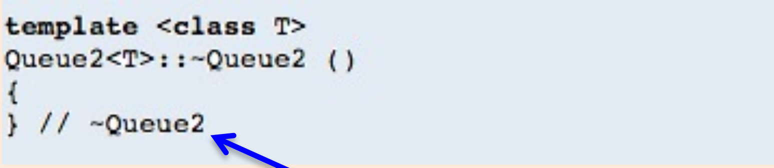
    ```
    self = <>
    ```

    and

    ```
    self = s.left * s.right
         = <> * <>
         = <>
    ```

The Destructor

- Has the same name as the constructor with a tilde prepended to the name
- The job of the destructor is to return dynamically allocated resources back to the system
- All data members from layered upon components: Have their destructors called when the variable goes out of scope, the C++ compiler guarantees this
- Because Queue is layered on List, no code is required for Queue's destructor, because List's destructor will automatically get called for data member *s*



```
template <class T>
Queue2<T>::~Queue2 ()
{
} // ~Queue2
```

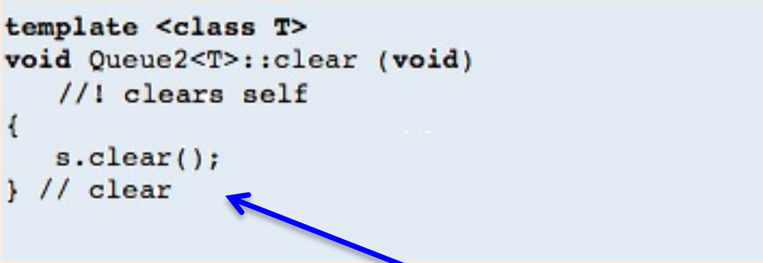
Example client:

```
{
  typedef Queue2<Integer> IntegerQueue;
  IntegerQueue q1, q2;

  // client code manipulating q1 and q2
  //         code is not shown
}
```

Queue() automatically called when q1 & q2 are declared

~Queue() automatically called as q1 & q2 go out of scope, so q1.s's destructor is called and q2.s's destructor is called

clear



```
template <class T>
void Queue2<T>::clear (void)
   //! clears self
{
   s.clear();
} // clear
```

- The job of the *clear* operation is to reset the value of the variable back to its initial value

- For Queue layered on List:

  - The spec for *clear* is:
    `clears self`

  - Recall the *correspondence*:
    `self = s.left * s.right`

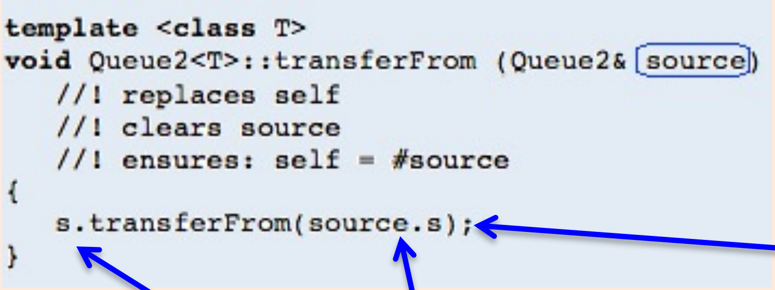
  - Queue's *clear* has to only call through to List's *clear* for the data member *s*:

    After calling `s.clear();`

    ```
    s = (<>,<>)

    self = s.left * s.right
         = <> * <>
         = <>
    ```

  - A *call through* is when an operation in a layered component simply calls the operation with the same name at the lower level, i.e., from the layered upon component – in this example Queue's *clear* calls List's *clear*

transferFrom



```
template <class T>
void Queue2<T>::transferFrom (Queue2& source)
   //! replaces self
   //! clears source
   //! ensures: self = #source
{
   s.transferFrom(source.s);
}
```

transferFrom works on two Lists:

1. *s* in front of the dot
2. source.s passed in as a parameter

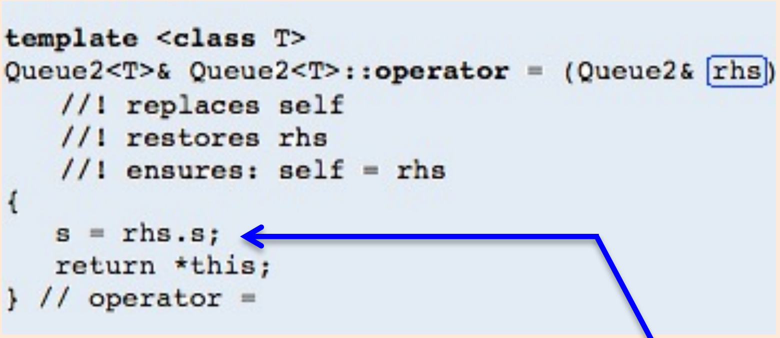
- The job of *transferFrom* is to transfer the value from the source variable to the controlling variable, i.e., the variable front of the dot
- For Queue layered on List:
  - This is easily accomplished by calling through to List's *transferFrom*
  - Queue2's *transferFrom* has parameter `source`
    - It is of type Queue2
    - List's *transferFrom* cannot be called as follows: `s.tranferFrom(source);`

      This would be a type mismatch because List's *transferFrom* works on two Lists

      So we must use the dot operator to dot our way into source's data member *s*, which of course is a List

      The correct call is:
      `s.tranferFrom(source.s);`

operator =



```
template <class T>
Queue2<T>& Queue2<T>::operator = (Queue2& rhs)
    //! replaces self
    //! restores rhs
    //! ensures: self = rhs
{
   s = rhs.s;
   return *this;
} // operator =
```

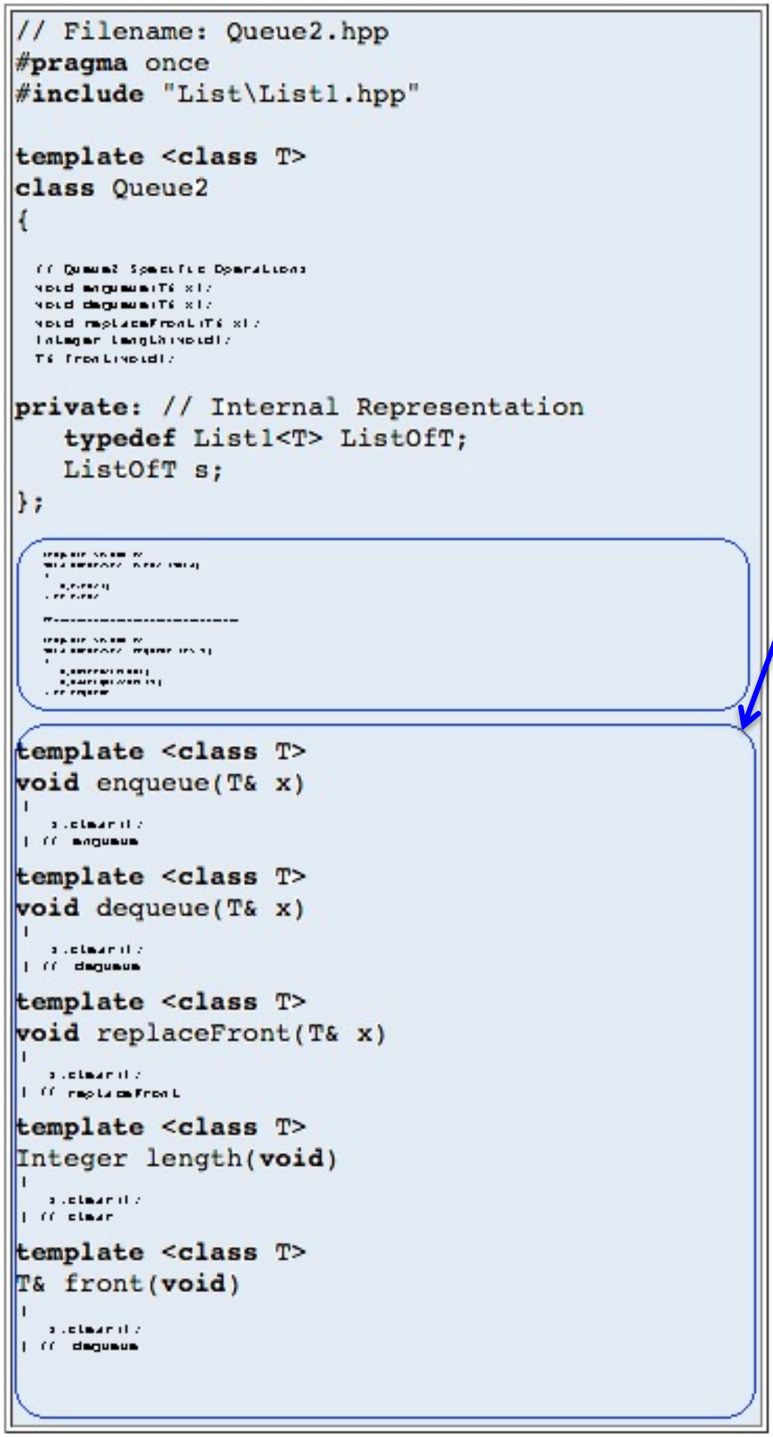
- In C++ *operator* = is the assignment operator, and its job is to make a copy of the variable that appears on the right-hand side (rhs) of the equals sign (=) and place the copy in the variable on the left-hand side (lhs)

Example client:

```
{
typedef Queue2<Integer> IntegerQueue;
IntegerQueue q1, q2;

q2 = q1;
// Or in C++ we could have written:
q2.operator=(q1);
// Both do the same thing, and both compile
}
```

- Queue's layered *operator* = is implemented by:
  - By calling through to List's *operator* =
  - Again, we have to use C++'s dot operator to gain access to the List inside of the parameter rhs
- `return *this;`

  In C++, the return statement is required so that clients can write code containing multiple assignments on one line, for example: `q2 = q1 = q3;`



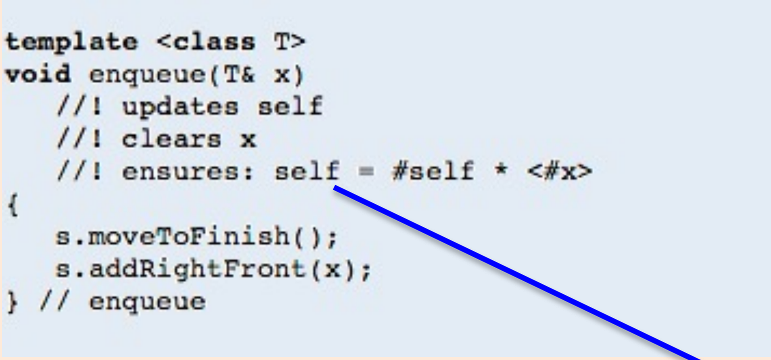
```
// Filename: Queue2.hpp
#pragma once
#include "List\List1.hpp"

template <class T>
class Queue2
{

  // Queue2 Specific Operations
  void enqueue(T& x);
  void dequeue(T& x);
  void replaceFront(T& x);
  Integer length(void);
  T& front(void);

private: // Internal Representation
   typedef List1<T> ListOfT;
   ListOfT s;
};

  [illegible]

template <class T>
void enqueue(T& x)
{
   s.clear();
} // enqueue

template <class T>
void dequeue(T& x)
{
   s.clear();
} // dequeue

template <class T>
void replaceFront(T& x)
{
   s.clear();
} // replaceFront

template <class T>
Integer length(void)
{
   s.clear();
} // clear

template <class T>
T& front(void)
{
   s.clear();
} // dequeue
```

Component Specific Operations

- Queue’s component specific operations are:

  1. enqueue
  2. dequeue
  3. replaceFront
  1. length
  2. front

enqueue



```
template <class T>
void enqueue(T& x)
   //! updates self
   //! clears x
   //! ensures: self = #self * <#x>
{
   s.moveToFinish();
   s.addRightFront(x);
} // enqueue
```

Example client:

```
{
   typedef Queue2<Integer> IntegerQueue;
   IntegerQueue q1;
   Integer y2;

   // Code not shown - enqueues 3 items onto q1
   // Incoming: q1 = <18,15,27>   y2 = 5
   q1.enqueue(y2);
   // Outgoing: q1 = <18,15,27,5>   y2 = 0
}
```

- *enqueue*'s ensures clause after substitution is:

  ```
  q1 = #q1 * <#y2> = <18,15,27> * <5>
     = <18,15,27,5>
  ```

- What value does *s* (inside q1) contain after *enqueue*?
  Answer: `s = (<18,15,27>,<5>)`

- How?

  `s.moveToFinish();` gave *s* the value:

  ```
  s = (<18,15,27>,<>)
  ```

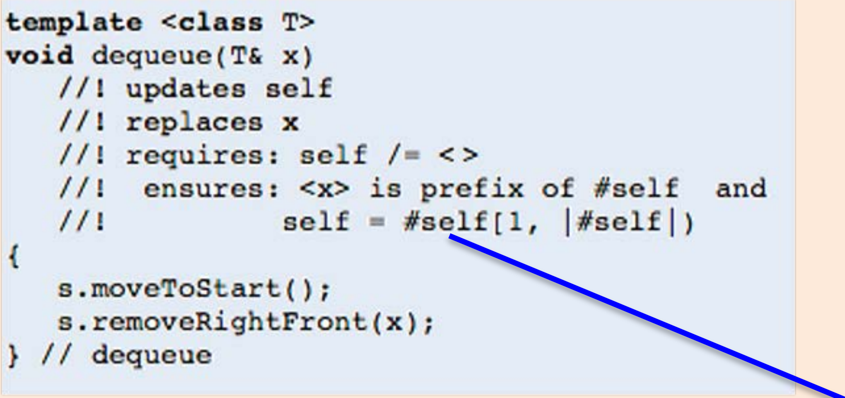
  `s.addRightFront(x);` gave *s* the value:

  ```
  s = (<18,15,27>,<5>)
  ```

- And using the *correspondence* we get:

  ```
  self = s.left * s.right
       = <18,15,27> * <5>
       = <18,15,27,5>
  ```

dequeue



```
template <class T>
void dequeue(T& x)
   //! updates self
   //! replaces x
   //! requires: self /= < >
   //!  ensures: <x> is prefix of #self  and
   //!               self = #self[1, |#self|)
{
   s.moveToStart();
   s.removeRightFront(x);
} // dequeue
```

Example client:

```
{
   typedef Queue2<Integer> IntegerQueue;
   IntegerQueue q1;
   Integer y2;

   // Incoming: q1 = <18,15,27>  y2 = 100
   q1.dequeue(y2);
   // Outgoing: q1 = <15,27>  y2 = 18
}
```

- *dequeue*'s ensures clause after substitution is:

```
   <y2> is prefix of <18,15,27> and
   q1 = <18,15,27>[1,3)
      = <15,27>
```

- What value does *s* (inside q1) contain after *dequeue*?
  Answer: `s = (<>,<15,27>)`

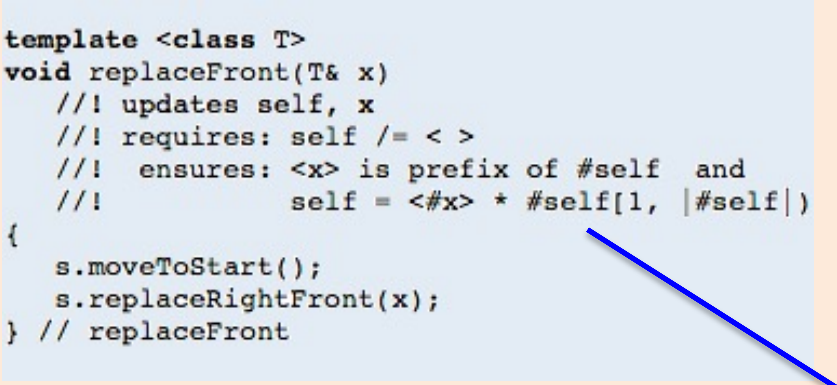
- How?

```
   s.moveToStart();  gave s the value:
      s = (<>,<18,15,27>)
   s.removeRightFront(x);  gave s the value:
      s = (<>,<15,27>)
```

- And using the *correspondence* we get:

```
   self = s.left * s.right
        = <> * <15,27>
        = <15,27>
```

replaceFront



```
template <class T>
void replaceFront(T& x)
   //! updates self, x
   //! requires: self /= < >
   //!  ensures: <x> is prefix of #self  and
   //!           self = <#x> * #self[1, |#self|)
{
   s.moveToStart();
   s.replaceRightFront(x);
} // replaceFront
```

Example client:

```
{
   typedef Queue2<Integer> IntegerQueue;
   IntegerQueue q1;
   Integer y2;

   // Incoming: q1 = <18,15,27>   y2 = 100
   q1.replaceFront(y2);
   // Outgoing: q1 = <100,15,27>   y2 = 18
}
```

- *replaceFront*'s ensures clause after substitution is:

```
<y2> is prefix of <18,15,27> and
q1 = <100> * <18,15,27>[1,3)
   = <100> * <15,27>
   = <100,15,27>
```

- How?

  `s.moveToStart();` gave *s* the value:

  `s = (<>,<18,15,27>)`

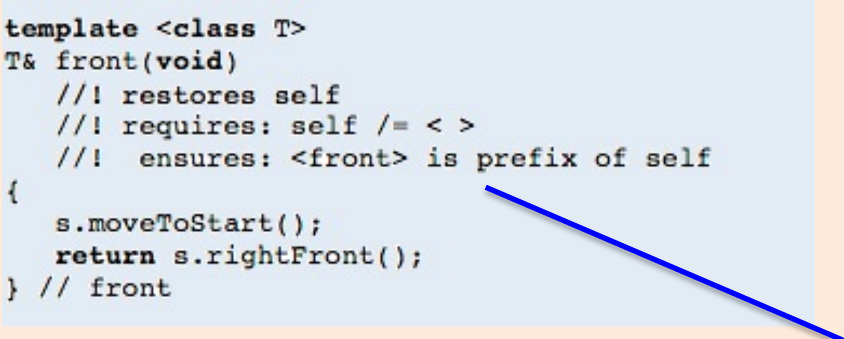
  `s.replaceRightFront(x);` gave *s* the value:

  `s = (<>,<100,15,27>)`

- And using the *correspondence* we get:

```
self = s.left * s.right
     = <> * <100,15,27>
     = <100,15,27>
```

front



```
template <class T>
T& front(void)
   //! restores self
   //! requires: self /= < >
   //!  ensures: <front> is prefix of self
{
   s.moveToStart();
   return s.rightFront();
} // front
```

Example client:

```
{
   typedef Queue2<Integer> IntegerQueue;
   IntegerQueue q1;

   // Incoming: q1 = <111,44>
   cout << q1.front();
   // Outgoing: q1 = <111,44> and 111 is output
}
```

- *front*'s ensures clause after substitution is:

  ```
  <front> is prefix of <111,44>
  <front> = <111>
  front = 111
  ```

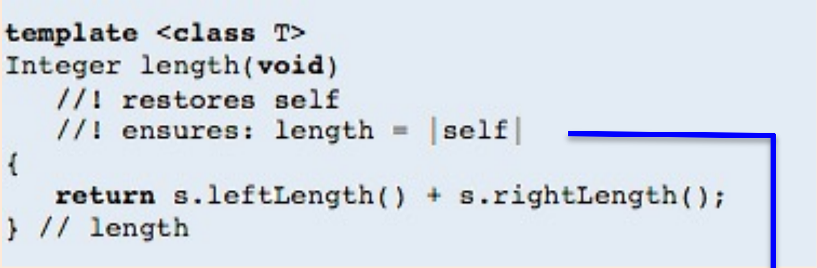
- Hand executing *front*'s code:

  `s.moveToStart();` gave *s* the value:

  ```
     s = (<>,<111,44>)
  ```

  `s.rightFront();` returns a reference to 111

length



```
template <class T>
Integer length(void)
   //! restores self
   //! ensures: length = |self|
{
   return s.leftLength() + s.rightLength();
} // length
```

Example client:

```
{
   typedef Queue2<Integer> IntegerQueue;
   IntegerQueue q1;
   Integer z;

   // Incoming: q1 = <18,15,27>   z = 0
   z = q1.length();
   // Outgoing: q1 = <18,15,27>   z = 3
}
```

- *length*'s ensures clause after substitution is:

```
   length = |<18,15,27>|
          = 3
```

- Because of the *correspondence* we know:

```
   self = s.left * s.right
```

  and we know:

```
   self = <18,15,27>
```

  so adding |s.left| and |s.right| must give us 3:

```
   s.leftLength() + s.rightLength() = 3
```

- In this example *s* could have anyone of 4 values:

```
  1.  s = (<>,<18,15,27>)
  2.  s = (<18>,<15,27>)
  3.  s = (<18,15>,<27>)
  4.  s = (<18,15,27>,<>)
```