Generics and The STL

CMPT 125
Mar. 13

Lecture 25

Today:

- Re-using Code Using Generics
- C++ `template`
- C++ Standard Template Library (STL)
  - `queue<T>`
  - `sort()`

Code Re-Use (Review)

If a piece of code can be employed for multiple purposes, then you *factor* the code

- Principle: Write it once, and then re-use it.

We built a Queue ADT for integers. Can we easily re-use the code for:

- doubles?
- strings?
- ordered pairs?

Use C++ `template`

Generic Programming

Express the algorithms so that they work on *any* type, to be specified as a parameter.

C++ uses the `template` construct to do this.

```
class queue {
  private:
    LL_t * intlist;
  public:
    queue();
    ~queue();
    int isEmpty();
    void enqueue(int data);
    int dequeue();
};
```

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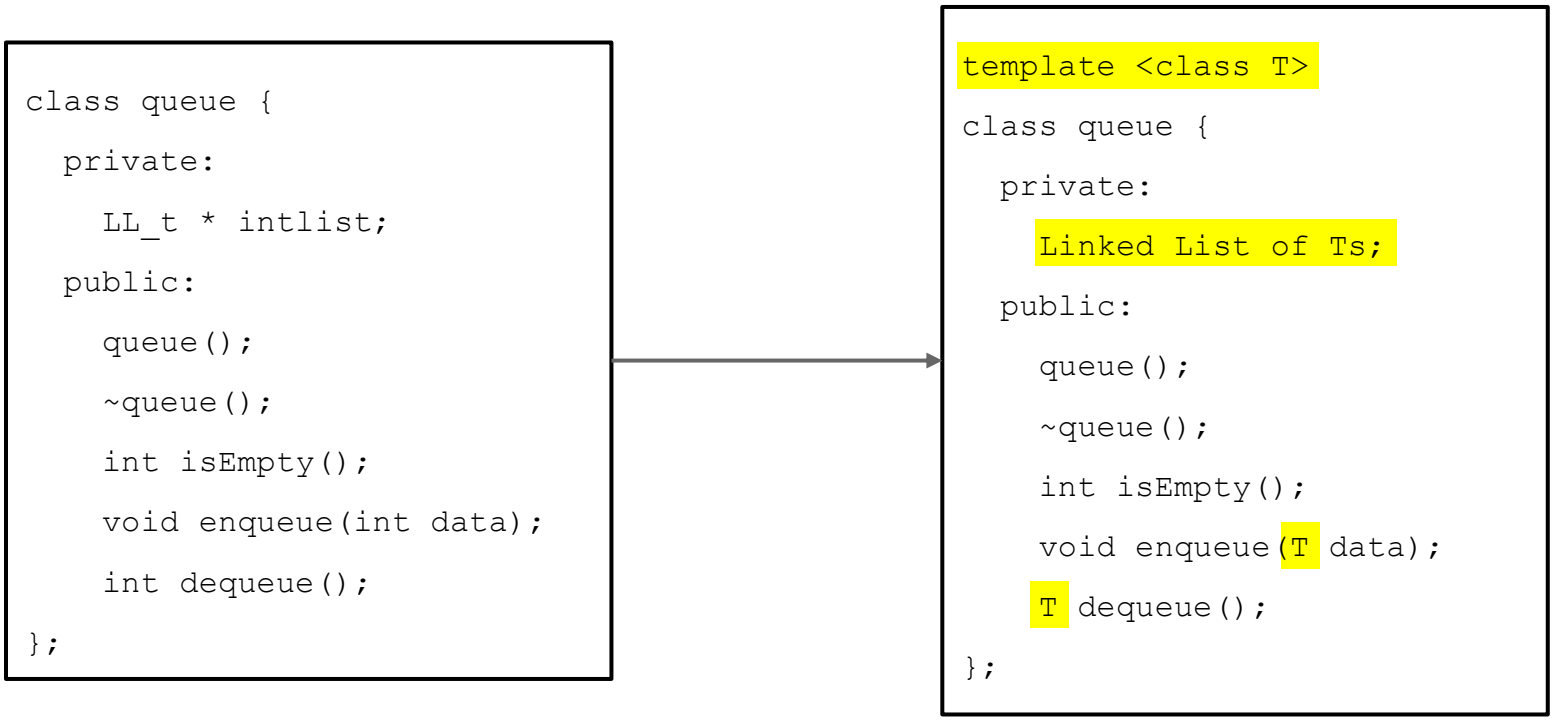

Implementing Generic Methods

- Implement all methods in the header file.
- Prefix is: `template <class T> class<T>::`
- The typename `T` will be substituted throughout.

```
int queue::isEmpty() {
    return list->isEmpty();
}


void queue::enqueue(int data) {
    list->append(data);
}


int queue::dequeue() {
    return list->removeHead();
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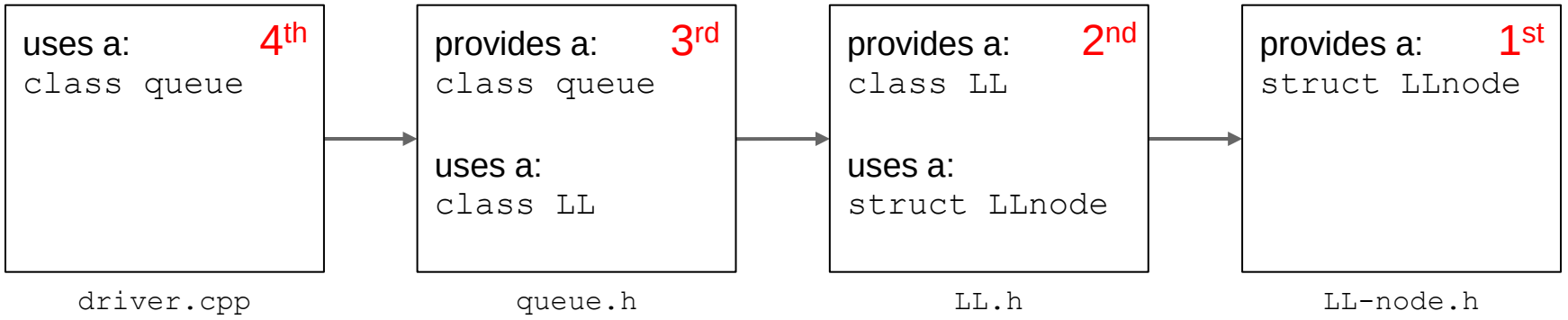
Example: Developing Generics

In our Queue ADT example, there was dependency among the code.



A *dependency graph* shows the dependency relationship among entities (files and classes)

- X → Y means that X depends on Y

Strategy: start at the end without dependencies

Compiling Your Code In Multiple Files

- Before, to compile C code, you used gcc
- Now, to compile C++ code, use g++

- Compile all files with automatically chosen output file (a.out)

```
g++ LL-node.h LL.cpp LL.h driver.cpp queue.cpp queue.h
```

- Compile all files but choose output file name (main)

```
g++ -o main LL-node.h LL.cpp LL.h driver.cpp queue.cpp queue.h
```

Some Useful g++ Options

- `-Wall`: turn most warnings on
- `-o` <name>: name of output file
- `-c`: output an object file (.o), used for multi-stage compilation
- `-I`<include path>: specify an include directory
- `-L`<include path>: specify an library directory

- `-g`: turn on debugging

Makefile

- A linux utility called “make” will look for a file called “makefile” in the same directory

- A makefile makes the compilation process more convenient
  - Only compiles files that have changed

Makefile

- Makefile contains blocks of instructions for compiling the code.

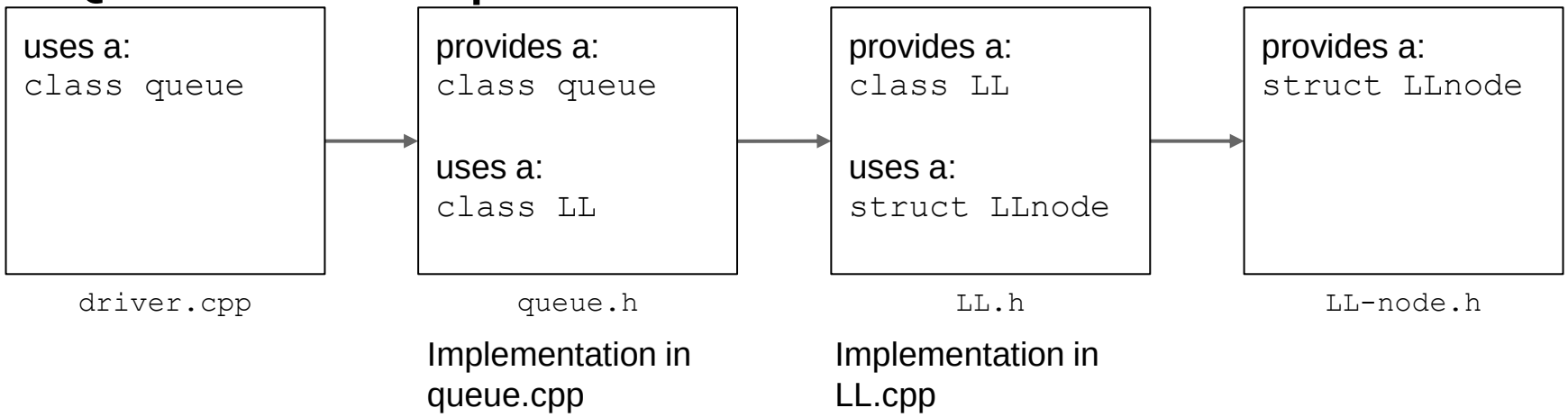
```
target: prerequisites
    command
    command
    …
```

tab is required!

- Each block contains three parts
  - “target”: name of executable or object file generated by g++, or name of action(s) to carry out
  - “prerequisites”: a list of files that are needed to create/perform the target (AKA dependencies)
  - “command”: the actual action to be carried out, in the form of a g++ command

Makefile

Queue example



- Compile LL and LL-node

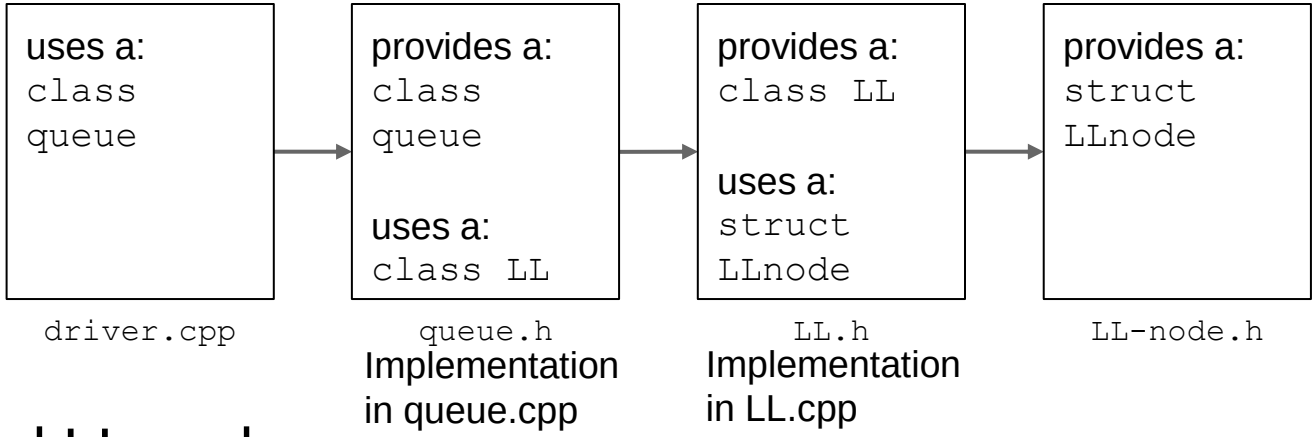
prerequisites

```
LL.o: LL.h LL.cpp LL-node.h
    g++ -Wall -c LL.cpp
```

target (output file)

command (just 1 command in this case)

Makefile



- Compile LL and LL-node

```
LL.o: LL.h LL.cpp LL-node.h
    g++ -Wall –c LL.cpp
```

- Compile queue

```
queue.o: LL.h queue.cpp queue.h
    g++ -Wall –c queue.cpp
```

- Compile driver

```
driver.o: driver.cpp queue.h
    g++ -Wall –c driver.cpp
```

- Compile driver, which includes all above compilations

```
driver: driver.o LL.o queue.o
    g++ -Wall –o driver driver.o queue.o LL.o
```

Makefile

- Cleaning up
- You always need a target called “clean”, that allows users to remove all compiled files
  - This allows us to share source code, and let the other person compile, instead of sharing the application

```
clean:
   rm –f driver *.o *.gch
```

Pitfalls with Generics

Some commands are not easily made generic

- E.g., `return -1;` in method `removeHead()`
- E.g., `printf( . . . )` in method `print()`

C++ offers some solutions:

- operator overloading
- streams
- exceptions

All of these are possible, but not wonderful

- . . . and not recommended
- . . . and beyond the scope of CMPT 125

C++ Standard Template Library (STL)

A collection of containers, definitions and algorithms for common use.

STL `queue<T>` Interface:

- `empty()` — same as `isEmpty()`
- `push(x)` — same as `enqueue(x)`
- `pop()` — similar to `dequeue()`, except no return value
- `front()` — returns a copy of the next item to be dequeued
- `back()` — returns a copy of the last item that was enqueued

```
#include <queue>



int main () {
    std::queue<int> *Q = new std::queue<int>;
    for (int i = 0; i < 5; i++)
        Q->push(i);
    while (!Q->empty()) {
        printf("front = %d, back = %d\n", Q->front(), Q->back());
        Q->pop();
    }
    delete Q;
    return 0;
}
```

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For more natural usage of the standard template library.

Generic `sort()` in STL

There are two versions of `sort()`:

- one that uses the built-in less than operator <
- one that uses your own comparison function

```
#include <algorithm>

using namespace std;

int main () {
    int arr[20];
    . . .
    . . .
    sort(arr, arr+20);
    . . .
    . . .
}
```

```
#include <algorithm>

using namespace std;

bool intCmp(int a, int b) {
    return a > b;
}

int main () {
    int arr[20];
    . . .
    . . .
    sort(arr, arr+20, intCmp);
    . . .
    . . .
}
```

Q. What's the difference between these?