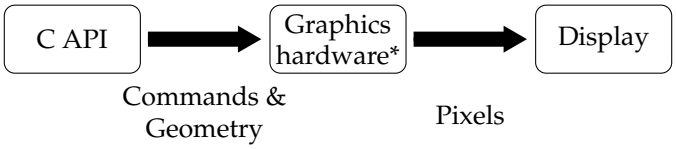
External Libraries

1 External libraries

- One of the reasons why C is so popular is the huge collection of tried and tested libraries available across many different computing platforms. E.g. OpenGL



- Commands from your program are sent by the API to the graphics hardware which generates pixels for display
- *in OpenGL the hardware behaves as a state machine

2 OpenGL programming

- On its own OpenGL is:
  1. Low level
  2. O/S independent
- Hence it is usually used with:
  - GLU a utility library with high level shape support
  - GLUT utility library for window creation and I/O

3 Commonly used C libraries

- general: `libglib` / `libgobject` / `libpthread`
- console: `libncurses`
- 2D graphics: `libX11` / `libSDL`
- 3D graphics: `libGL` / `libGLU` / `libGLUT`
- GUI toolkits: `libgtk` / `libQT`
- Images: `libjpeg` / `libpng` / `libgif`
- text rendering: `libpango` / `libfreetype`
- sound: `libasound` / `libSDL`
- compression: `libz` (`zlib`) / `libgzip` / `libbz2`
- encryption: `libcrypt` / `libssl` / `libgssapi` / `libkrb5`
- XML: `libxml2`
- web: `libcurl`

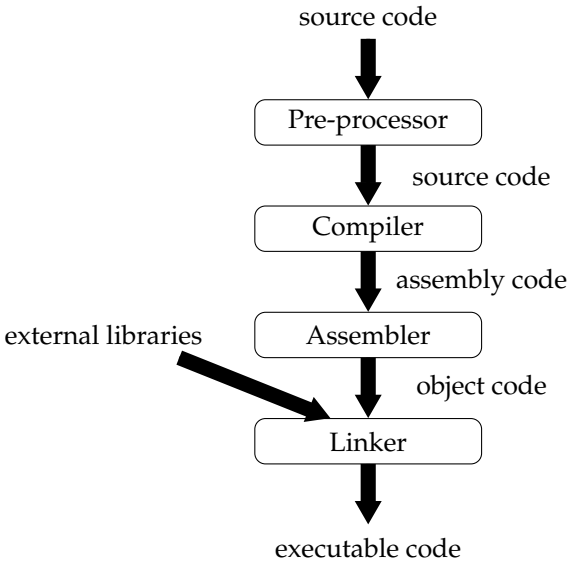
4 Usage of libraries

- If a library is *statically linked* then a copy of the library is included in the executable
  - No need to worry about what version of the library you have
- C/C++/assembly can be combined
- Often bound to other languages e.g. php, XML, curl
- Many of these libraries will be *dynamically linked*
- Try `ldd /usr/bin/php` on Linux to list dynamic dependencies

5 Dynamic vs static linking

- *Dynamic* linking takes place at run-time not build-time
  - Reduces filespace demands (bloat) by keeping only one copy of the library
  - Only one copy of the library is loaded into memory
  - Can help with updates e.g. for security
  - Using dynamic linking can be slightly slower than static linking
- LGPL (Lesser Gnu Public License) often used
- Dynamic libraries are called differently by OSs
- Linux: shared objects (`.so`)
- Windows: Dynamic Link Libraries (`.dll`)
- OSX: `.dylib`
- Can lead to "DLL Hell": many versions of the same dynamic library
- Best to include version number with library

6 Compilation Model



7 Creating a static library

- A static library is effectively just an archive containing object (`.o`) files and is created with the archiver `ar`.
- On UNIX, static libraries use the `.a` extension.

```
gcc -c linkedlist.c -o bin/static/linkedlist.o
gcc -c anotherfile.c -o bin/static/anotherfile.o
ar rcs bin/static/libLL.a bin/static/linkedlist.o \
    bin/static/anotherfile.o
```

- To link statically:
  - Use the `-L` flag to list a (non-standard) directory where the library can be found
  - Use the `-l` flag to give the name of the library. Note that it assumes the library starts with `lib` and has the extension `.a` (static) or `.so` (dynamic)

```
gcc  main.o  -Lbin/static -lLL -o bin/main-static
```

- Can now run

```
bin/main-static
```

8 Loading/unloading a library

- We can add code to see when a library is loaded into memory and when it is unloaded.
  - N.B. This is a `gcc` extension and might not work on other compilers.

```
void __attribute__ ((constructor)) initLibrary(void){
 printf("Library is being loaded\n");
}

void __attribute__ ((destructor)) cleanUpLibrary(void){
 printf("Library is being exited\n");
}
```

9 Creating a shared library

- Objects files for a shared library need to be compiled with the `-fPIC` option
- On UNIX, static libraries use the `.so` extension.
  - PIC="Position Independent Code", since we don't know where in memory the library will be loaded at run-time

```
gcc -fPIC -c linkedlist.c -o bin/dynamic/linkedlist.o
gcc -fPIC -c anotherfile.c -o \
    bin/dynamic/anotherfile.o
gcc -shared bin/dynamic/linkedlist.o \
    bin/dynamic/anotherfile.o -o bin/dynamic/libLL.so
```

- To link dynamically:

```
gcc   main.o  -Lbin/static -lLL -o bin/main-static
```

- If we try to run it, we get an error:

```
bin/main-shared: error while loading shared libraries:
    libLL.so: cannot open shared object file: No such
    file or directory
```

- Need to tell the operating system where to find the library:

```
# In bash:
LD_LIBRARY_PATH=`pwd`/bin/dynamic/:$LD_LIBRARY_PATH
# In tcsh (the default shell on mira):
setenv LD_LIBRARY_PATH \
    `pwd`/bin/dynamic:$LD_LIBRARY_PATH
```

- (Note that ` above is a backtick)

10 Function Pointers

- We've seen pointers to variables. We can also have pointers to functions!

```
#include<stdio.h>
void hello_function(int times);

int main(){
  void (*func_ptr)(int);
  func_ptr=hello_function;
  func_ptr(3);
  return 0;
}
```

```
void hello_function(int times){
  for(int i=0;i<times;i++) {
    printf("Hello, World!\n");
  }
}
```

11 Using qsort()

- stdlib.h contains an implementation of the quicksort algorithm. The function declaration is:

```
void qsort(void *base, size_t nmemb, size_t size,
    int (*compar)(const void *, const void *))
```

- void *base is a pointer to the array
- size_t nmemb is the number of elements in the array
- size_t size is the size of each element
- int (*compar)(const void *, const void *) is a function pointer composed of two arguments and returns '0 when the arguments have the same value, <0 when arg1 comes before arg2, and >0 when arg1 comes after arg2.

```
#include <stdio.h>
#include <stdlib.h>
int compare (const void *, const void *);
int main() {
  int arr[] = {52, 14, 50, 48, 13};
  int num, width, i;
  num = sizeof(arr)/sizeof(arr[0]);
  width = sizeof(arr[0]);
  qsort(arr, num, width, compare);
  for (i = 0; i < 5; i++)
    printf("%d ", arr[i]);
  printf("\n");
  return 0;
}

int compare (const void *arg1, const void *arg2) {
  return *(int *)arg1 - *(int *)arg2;
}
```

12 Implement calloc() and realloc().

- Write functions calloc2() and realloc2(), that use malloc() and free() to implement the functionality of calloc() and realloc(), respectively.
- Remember that calloc() sets the allocated memory to zero (for this exercise, you may ignore testing for integer overflows when multiplying the arguments of calloc() together).
- When implementing the copying part of realloc(), recall that char is 1 byte; the C standard states that you may use char * pointers to access individual bytes of memory.