Start-Up and Shut-Down

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Subsystem Start-up and Shut-Down

- Interdependence of subsystems
  → required order for start-up and shut-down
- Often subsystems are singleton classes (managers)

Static Initialization

```
class RenderManager {
    public:
        RenderManager() {
          // Start up the manager
        }
        ~RenderManager() {
          // Shut down the manager
        }
};
static RenderManager gRenderManager;
```

Static Initialization

- Global and static objects are constructed before main() is called and destroyed after main() returns
- BUT: In unpredictable order!

Initialization

- Typical solution
  - The global singleton is a static variable inside a „get()“ function, so initalized when retrieved for the first time
- Problems
  - „get“ is not an obvious initialization function
  - Destruction is still arbitrary

Initialization

- Better Solution
  - EXPLICIT startup/shutdown

Explicit Initialization

```
class RenderManager {
    public:
        RenderManager() { // nothing  }
        ~RenderManager() { // nothing }
        void startUp() { // initialize here }
        void shutDown() { // clean up here }
    };
RenderManager gRenderManager;
int main(int argc, const char* argv) {
  gRenderManager.startUp();  ... }
```

Initialization

- Better Solution
  - EXPLICIT startup/shutdown
- Benefits
  - Simple
  - Explicit
  - Facilitates debugging

Memory Management

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RAM and Performance

- RAM use affects performance
  1. Dynamic allocation is slow
  2. Memory access patterns are important

Dynamic Allocation

- OS Heap Allocator is complex and deals with things like contention between threads. Context switching often required.
- Avoid as much as possible and never use this allocator in a tight loop!
- Games typically implement their own memory allocators.

Custom Memory Allocators

- STACK-BASED Allocators
  - Allocates a contiguous block that can grow
  - Only able to free by popping back to a marker
- DOUBLED-ENDED STACK Allocator
  - Two stacks, one from each end
  - One stack for „slowly“ changing data (e.g. levels) and one for „faster“ changing data (e.g. temps)

Custom Memory Allocators

- POOL Allocators
  - Only allocate same sized blocks
  - Free blocks kept in a single linked list
  - Fast manipulation
- ALIGNED Allocators
  - When allocators make sure that returned addresses are properly data aligned for the CPU
  - Typically allocate additional size of alignment and then adjust address upwards until it fits

Custom Memory Allocation

- SINGLE-FRAME Allocators
  - A single stack allocator that gets cleared at beginning of every render loop
- SOUBLE-BUFFERED Allocators
  - Two stack allocators that get swapped at beginning of every render loop, and then the new current one gets cleared
  - Data from previous frame still available
- Danger: Memory „destroyed“ instead of freed

Memory Fragmentation

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Memory Blocks

- Allocated memory blocks must be contiguous
- Problem is that after many allocations and freeing of memory, there will be free areas of various sizes, but perhaps none big enough to hold a single large memory block
- This is the problem of fragmentation

Avoiding Fragmentation

- Use
  - Stack allocator (always contiguous)
  - Pool allocator (always same block size)

Defragmentation

- Combine all the free memory into a contiguous block
- Could shift allocated blocks to lower addresses, letting the free memory „bubble up“

Defragmentation: Relocation

- Shifting allocated memory requires the relocation of pointers!
  - Need to find those pointers and change them
  - This can be hard
- Possible to use
  - Smart pointers: Classes that register themselves
  - Handles: Indecies into pointer tables

Defragmentation: Reduce cost

- When blocks are relatively small, it is easy to spread their defragmentation across many frames
- Possible to break up larger blocks

Cache Coherency

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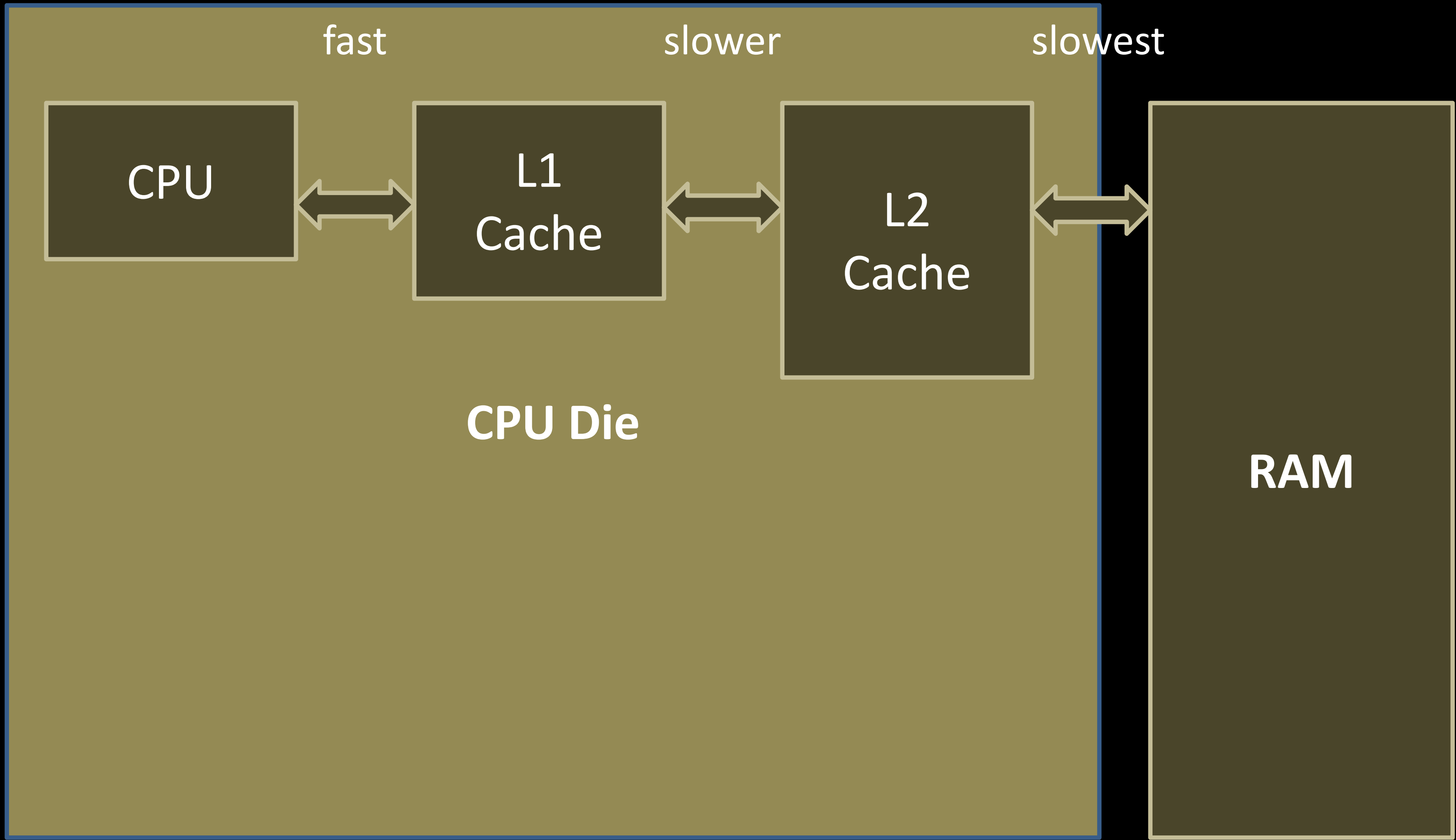
Cache Levels



Types of Cache

- Data Cache (D-Cache)
  - Cache lines contain data that hopefully gets used next
- Instruction Cache (I-Cache)
  - Cache lines contain machine code that hopefully gets executed next

Avoid Misses

- Avoid D-Misses
  - Organize data contiguously
  - Keep it in small chunks (to fit in cache line)
- Avoid I-Misses
  - Keep high-performance machine code as small as possible
  - Avoid calling functions from high-performance code
  - Place other functions close by (translation units stay together in memory)