CUDA Programming

Recap

- Write a CUDA code corresponding to the following sequential C code.

```
#include <stdio.h>
#define N 100
int main() {
    int i;
    for (i = 0; i < N; ++i)
        printf("%d\n", i * i);
    return 0;
}
```

```
#include <cuda.h>
#define N 100
__global__ void fun() {
        printf("%d\n", threadIdx.x *
                              threadIdx.x);
}
int main() {
        fun<<<1, N>>>();
        cudaDeviceSynchronize();
        return 0;
}
```

Note that there is no loop here.

Classwork

- Write a CUDA code corresponding to the following sequential C code.

```
#include <stdio.h>
#define N 100
int main() {
    int a[N], i;
    for (i = 0; i < N; ++i)
        a[i] = i * i;
    return 0;
}
```

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#define N 100
int main() {
    int a[N], i;
    for (i = 0; i < N; ++i)
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    return 0;
}
```

```
#include <stdio.h>
#include <cuda.h>
#define N 100
__global__ void fun(int *a) {
        a[threadIdx.x] = threadIdx.x * threadIdx.x;
}
int main() {
        int a[N], *da;
        int i;
        cudaMalloc(&da, N * sizeof(int));
        fun<<<1, N>>>(da);
        cudaMemcpy(a, da, N * sizeof(int),
                        cudaMemcpyDeviceToHost);
        for (i = 0; i < N; ++i)
                printf("%d\n", a[i]);
        return 0;
}
```

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#define N 100
int main() {
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```

Observation

No cudaDeviceSynchronize required.

```
#include <stdio.h>
#include <cuda.h>
#define N 100
__global__ void fun(int *a) {
        a[threadIdx.x] = threadIdx.x * threadIdx.x;
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int main() {
        int a[N], *da;
        int i;
        cudaMalloc(&da, N * sizeof(int));
        fun<<<1, N>>>(da);
        cudaMemcpy(a, da, N * sizeof(int),
                        cudaMemcpyDeviceToHost);
        for (i = 0; i < N; ++i)
                printf("%d\n", a[i]);
        return 0;
}
```

Hello World with a Global.

```
#include <stdio.h>
#include <cuda.h>
const char *msg = "Hello World.\n";
__global__ void dkernel() {
    // no-op
}
int main() {
    printf(msg);
    return 0;
}
```

GPU Hello World with a Global.

```
#include <stdio.h>
#include <cuda.h>
const char *msg = "Hello World.\n";
__global__ void dkernel() {
    printf(msg);
}
int main() {
    dkernel<<<1, 32>>>();
    cudaDeviceSynchronize();
    return 0;
}
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GPU Hello World with a Global.

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#include <stdio.h>
#include <cuda.h>
const char *msg = "Hello World.\n";
__global__ void dkernel() {
    printf(msg);
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Compile: nvcc hello.cu
error: identifier "msg" is undefined in device code

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Takeaway

CPU and GPU memories are separate (for discrete GPUs).

GPU Hello World with a Global.

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#include <stdio.h>
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#define msg "Hello World.\n"
__global__ void dkernel() {
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CPU and GPU memories are separate (for discrete GPUs).

GPU Hello World with a Global.

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#include <stdio.h>
#include <cuda.h>
#define msg "Hello World.\n"
__global__ void dkernel() {
    printf(msg);
}
int main() {
    dkernel<<<1, 32>>>();
    cudaDeviceSynchronize();
    return 0;
}
```

Compile: nvcc hello.cu
Run: ./a.out
Hello World.
Hello World.
...

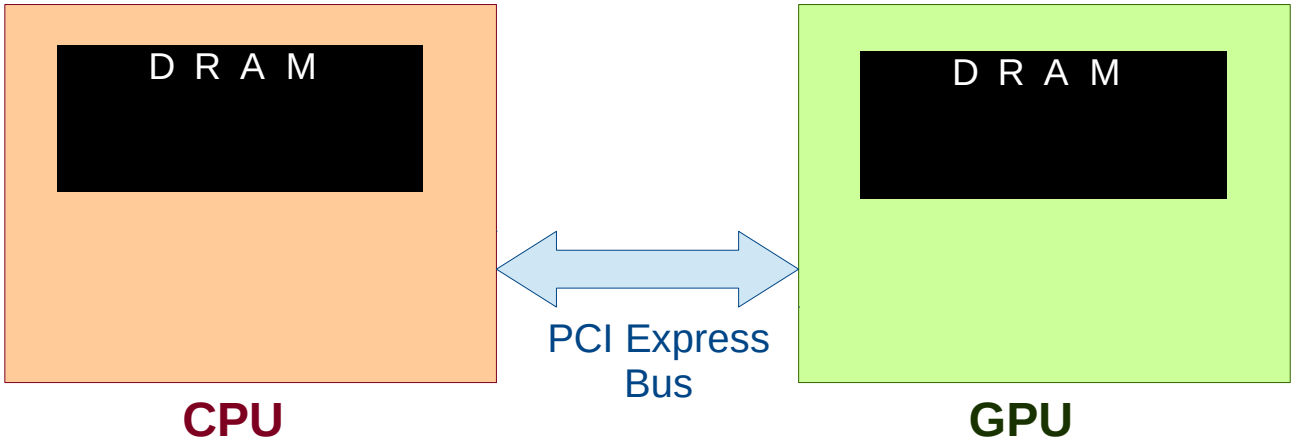
Takeaway

CPU and GPU memories are separate (for discrete GPUs).

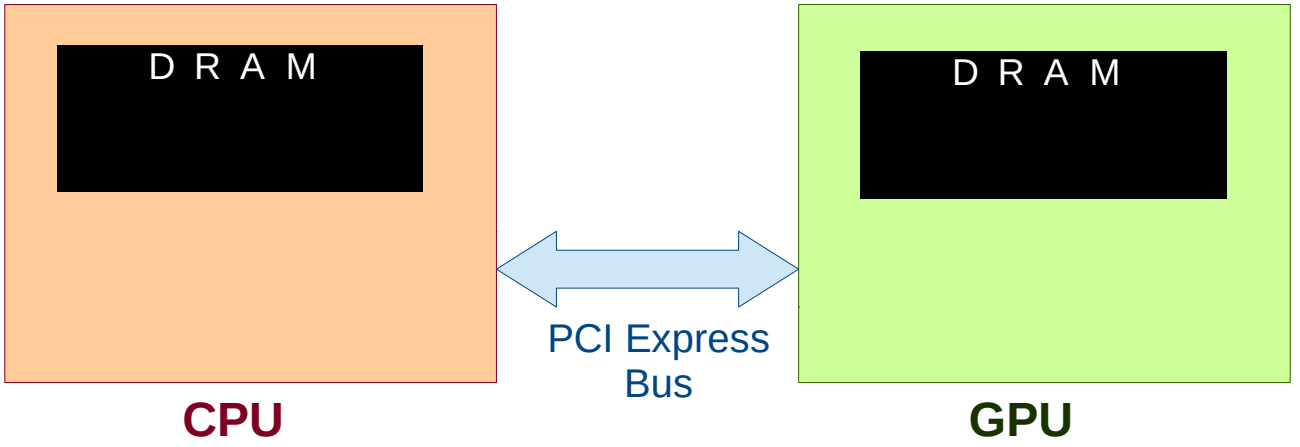
#define msg “Hello World.\n”

is okay.

Separate Memories



Separate Memories



- CPU and its associated (discrete) GPUs have separate physical memory (RAM).
- A variable in CPU memory cannot be accessed directly in a GPU kernel.

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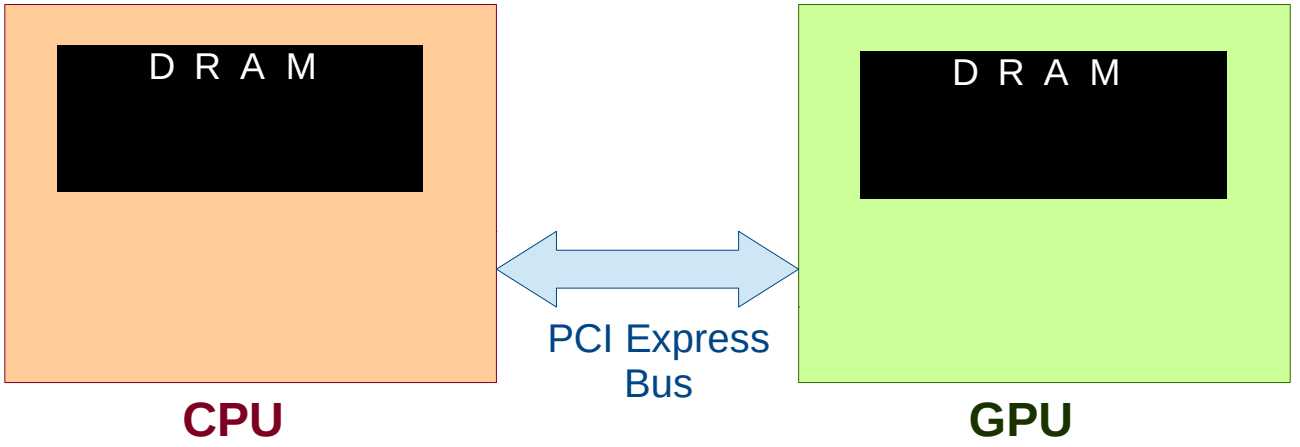
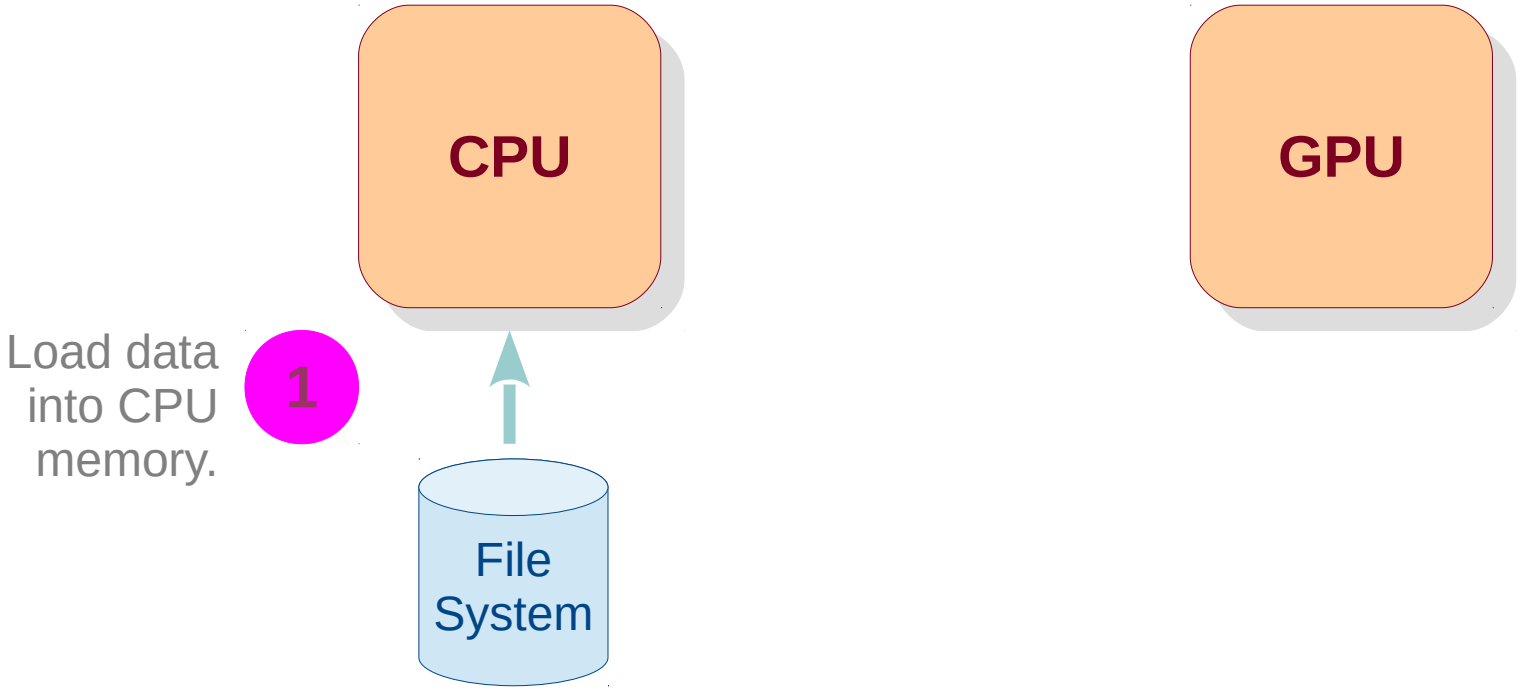


- CPU and its associated (discrete) GPUs have separate physical memory (RAM).
- A variable in CPU memory cannot be accessed directly in a GPU kernel.
- A programmer needs to maintain copies of variables.
- It is programmer's responsibility to keep them in sync.

Typical CUDA Program Flow



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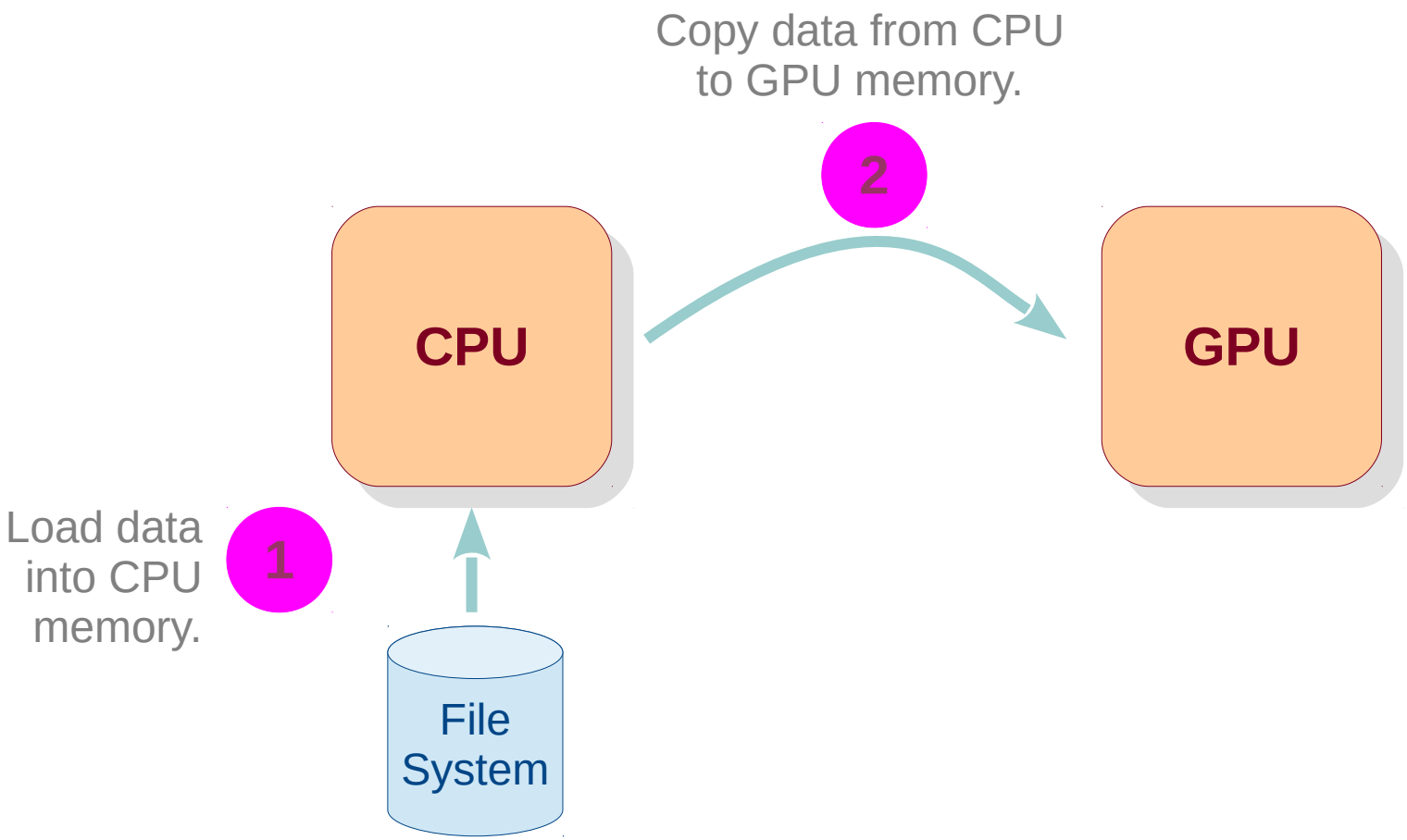
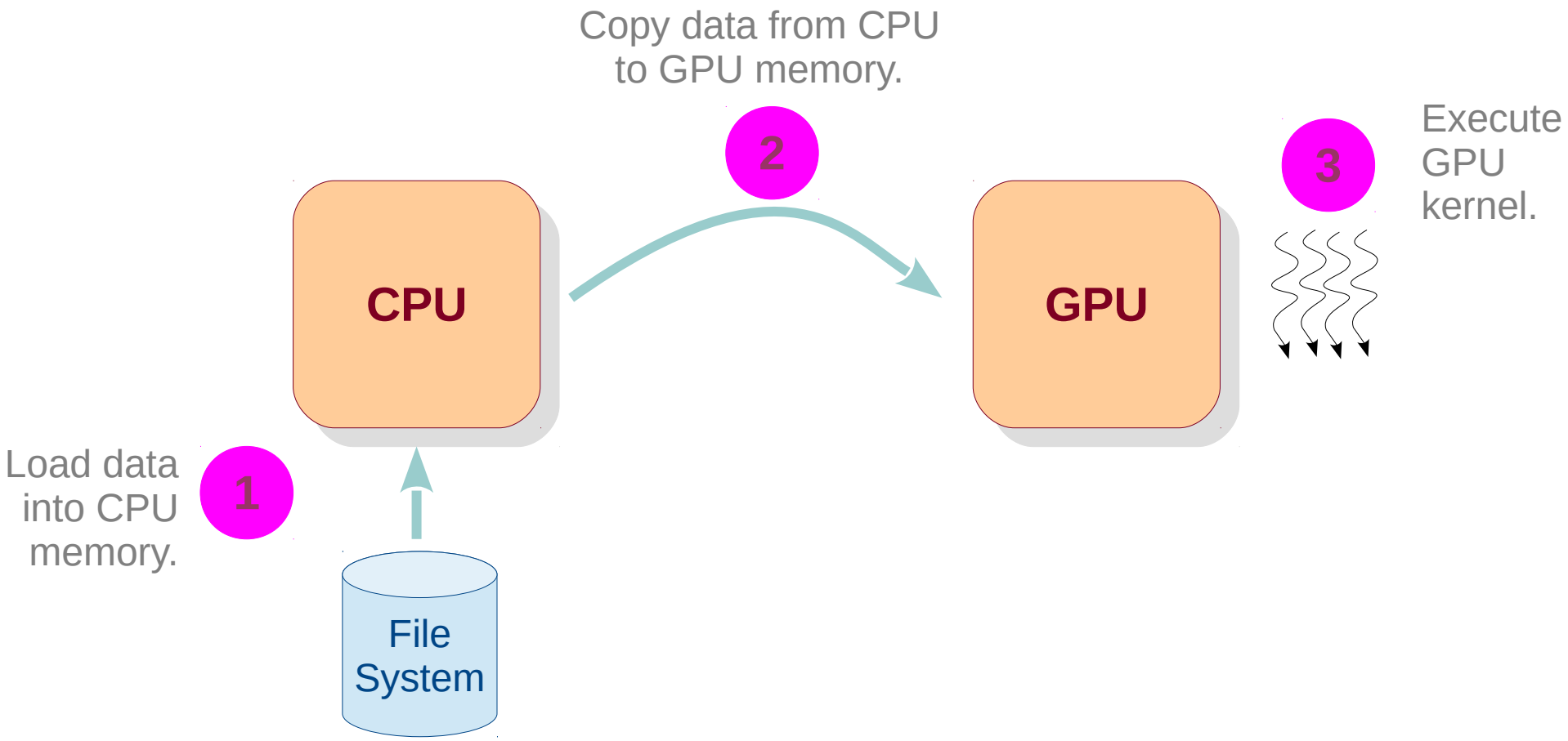
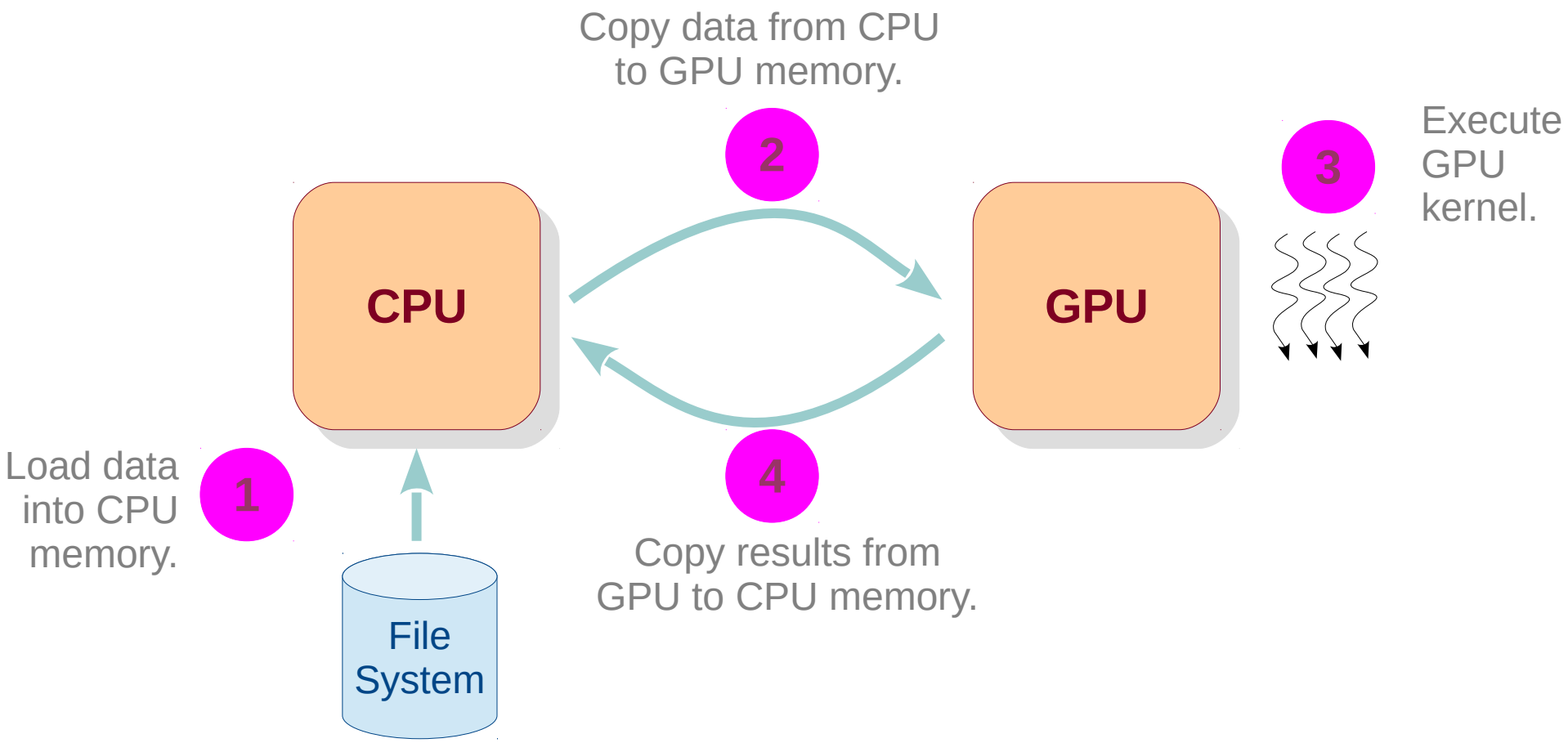


Typical CUDA Program Flow



Typical CUDA Program Flow



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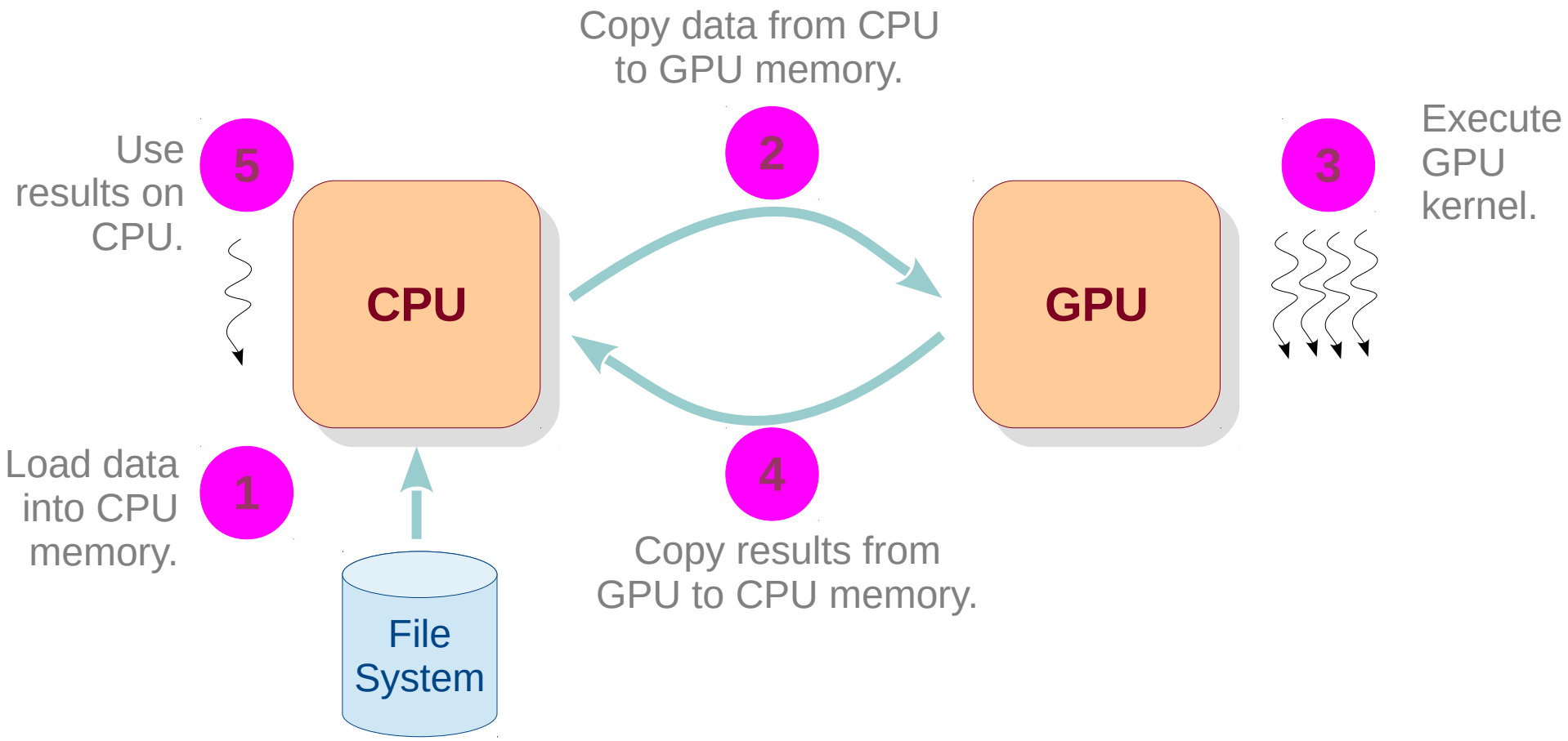

Typical CUDA Program Flow

1. Load data into CPU memory.
   - fread / rand
2. Copy data from CPU to GPU memory.
   - cudaMemcpy(..., cudaMemcpyHostToDevice)
3. Call GPU kernel.
   - mykernel<<<x, y>>>(...)
4. Copy results from GPU to CPU memory.
   - cudaMemcpy(..., cudaMemcpyDeviceToHost)
5. Use results on CPU.

Typical CUDA Program Flow

2. Copy data from CPU to GPU memory.

   - cudaMemcpy(..., cudaMemcpyHostToDevice)

This means we need two copies of the same variable – one on CPU another on GPU.

e.g., int *cpuarr, *gpuarr;

Matrix cpumat, gpumat;

Graph cpug, gpug;

CPU-GPU Communication

```
#include <stdio.h>
#include <cuda.h>
__global__ void dkernel(char *arr, int arrlen) {
        unsigned id = threadIdx.x;
        if (id < arrlen) {
                ++arr[id];
        }
}
```

```
int main() {
    char cpuarr[] = "Gdkkn\x1fVnqkc-",
         *gpuarr;

    cudaMalloc(&gpuarr, sizeof(char) * (1 + strlen(cpuarr)));
    cudaMemcpy(gpuarr, cpuarr, sizeof(char) * (1 + strlen(cpuarr)), cudaMemcpyHostToDevice);
    dkernel<<<1, 32>>>(gpuarr, strlen(cpuarr) + 1 );
    cudaDeviceSynchronize();        // unnecessary, but okay.
    cudaMemcpy(cpuarr, gpuarr, sizeof(char) * (1 + strlen(cpuarr)), cudaMemcpyDeviceToHost);
    printf(cpuarr);

    return 0;
}
```

CPU-GPU Communication

```
#include <stdio.h>
#include <cuda.h>
__global__ void dkernel(char *arr, int arrlen) {
        unsigned id = threadIdx.x;
        if (id < arrlen) {
                ++arr[id];
        }
}
```

```
int main() {
    char cpuarr[] = "Gdkkn\x1fVnqkc-",
         *gpuarr;

    cudaMalloc(&gpuarr, sizeof(char) * (1 + strlen(cpuarr)));
    cudaMemcpy(gpuarr, cpuarr, sizeof(char) * (1 + strlen(cpuarr)), cudaMemcpyHostToDevice);
    dkernel<<<1, 32>>>(gpuarr, strlen(cpuarr));
    cudaDeviceSynchronize();        // unnecessary, but okay.
    cudaMemcpy(cpuarr, gpuarr, sizeof(char) * (1 + strlen(cpuarr)), cudaMemcpyDeviceToHost);
    printf(cpuarr);

    return 0;
}
```

Classwork

1. Write a CUDA program to initialize an array of size 32 to all zeros in parallel.

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2. Change the array size to 1024.
3. Create another kernel that adds *i* to *array[i]*.
4. Change the array size to 8000.
5. Check if answer to problem 3 still works.

Homework ($z = x^2 + y^3$)

- Read a sequence of integers from a file.
- Square each number.
- Read another sequence of integers from another file.
- Cube each number.
- Sum the two sequences element-wise, store in the third sequence.
- Print the computed sequence.