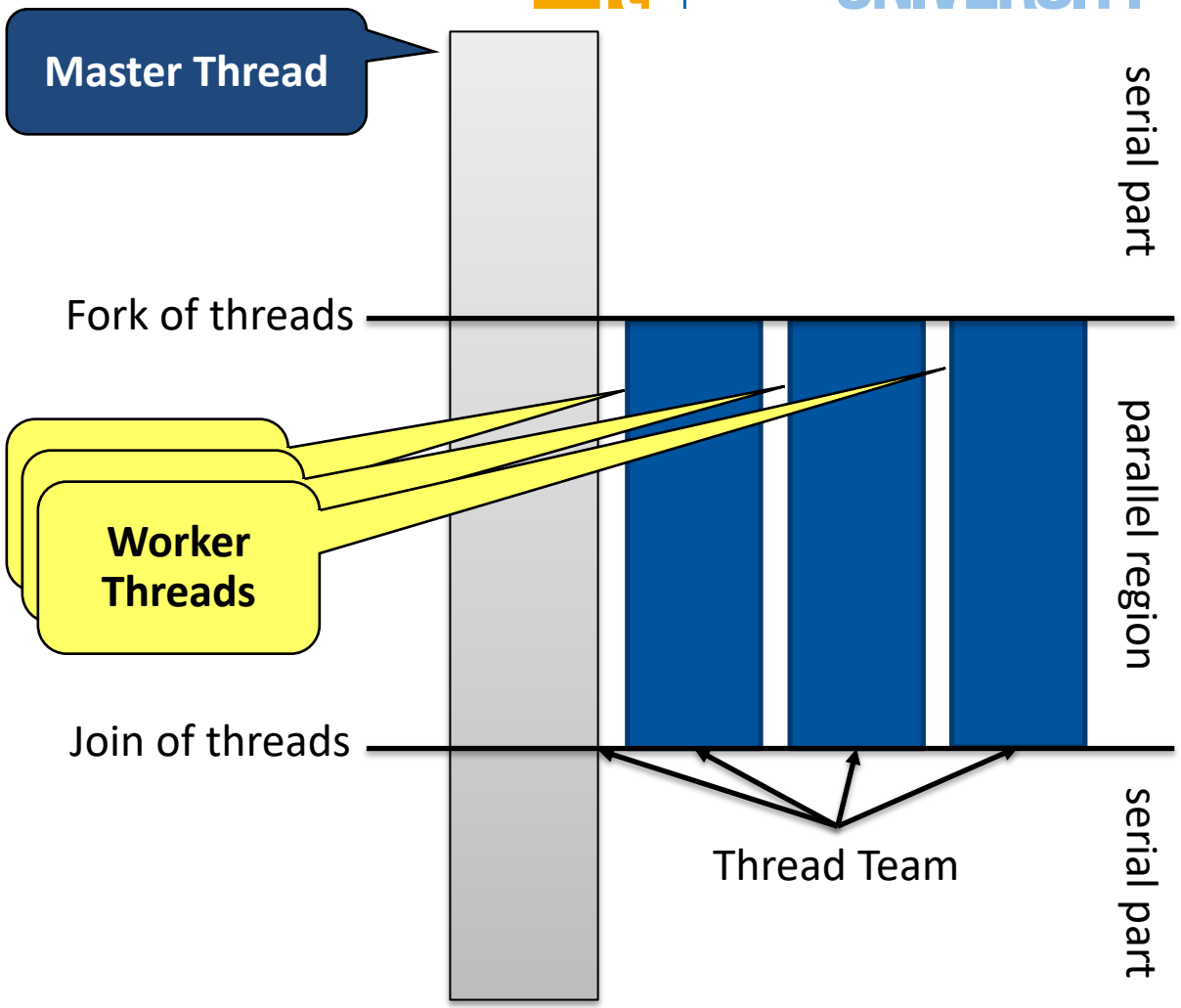
Summary: Introduction to OpenMP

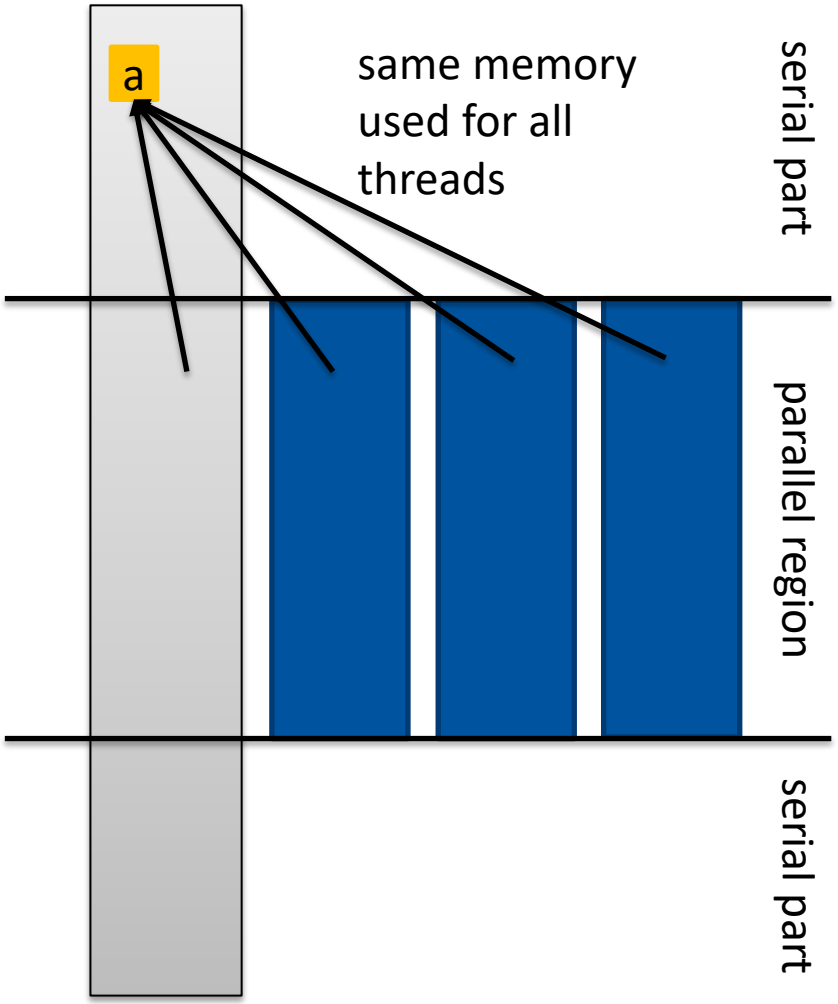
Fork-Join Execution Model

```
.
.
.
#pragma omp parallel
{
.
.
.
.
}
.
.
.
```



Data Sharing Attributes

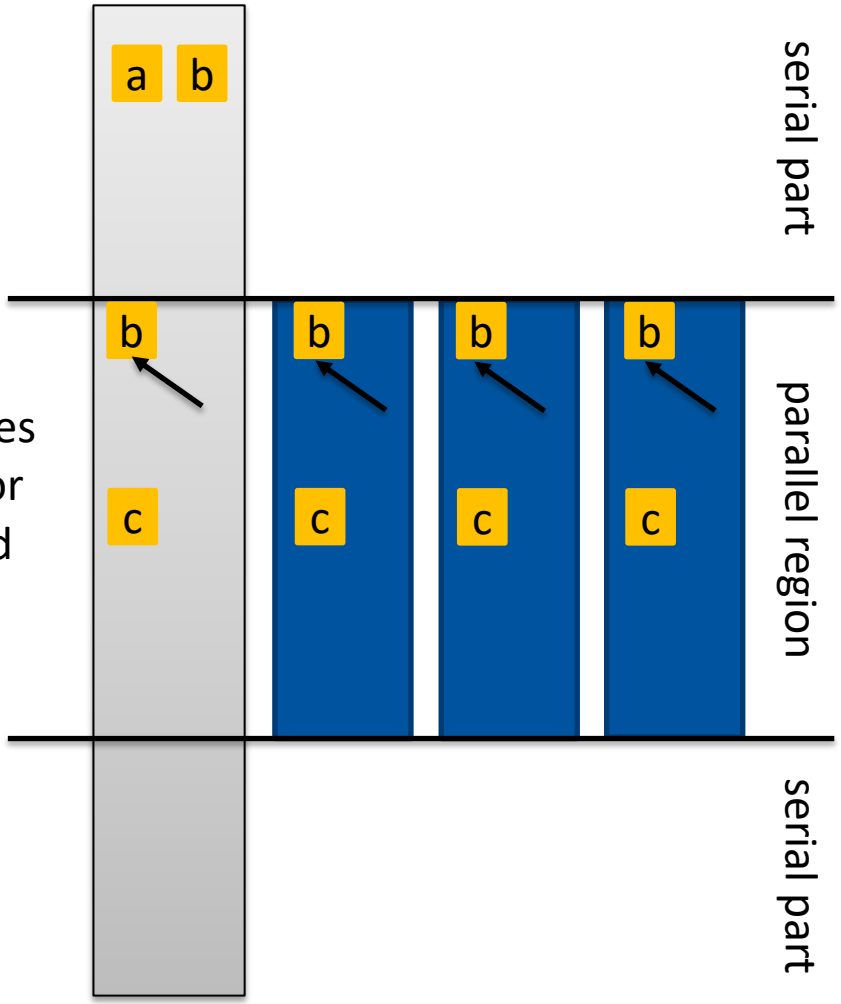
```
int a;
.
.
#pragma omp parallel shared(a)
{
.
.
.
.
}
.
.
.
```



Data Sharing Attributes

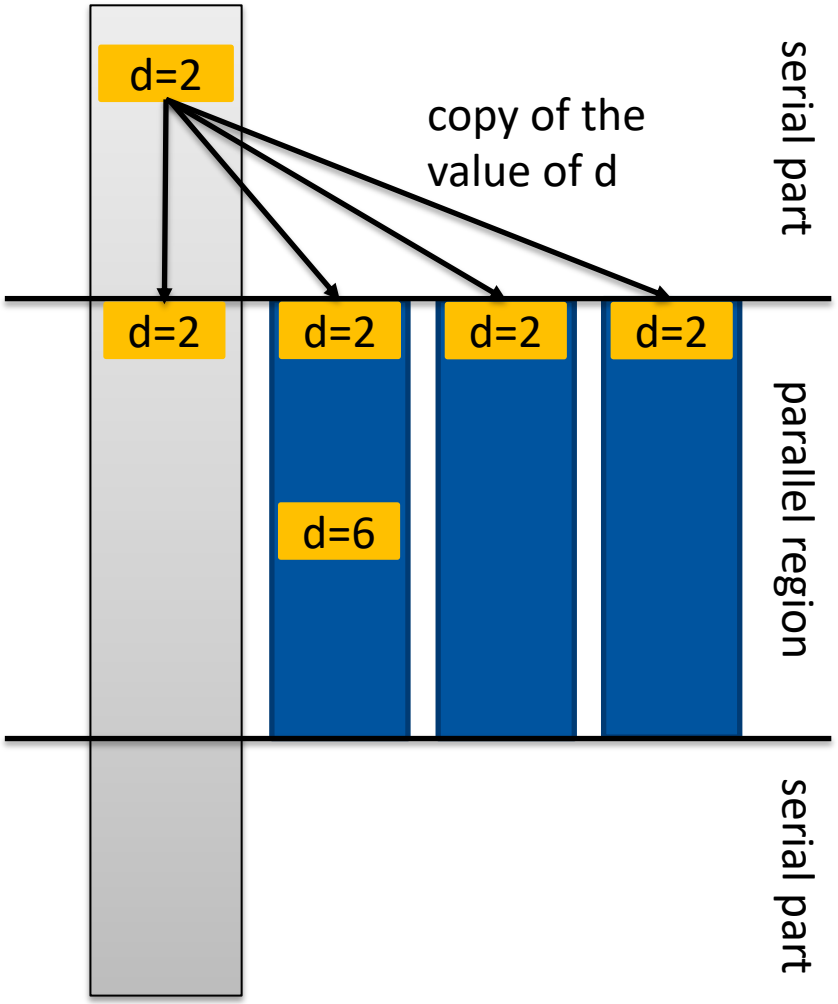
```
int a,b;
.
#pragma omp parallel shared(a) //
  private(b)
{
.
int c;
.
}
.
.
.
```

uninitialized private copies of b and c for every thread



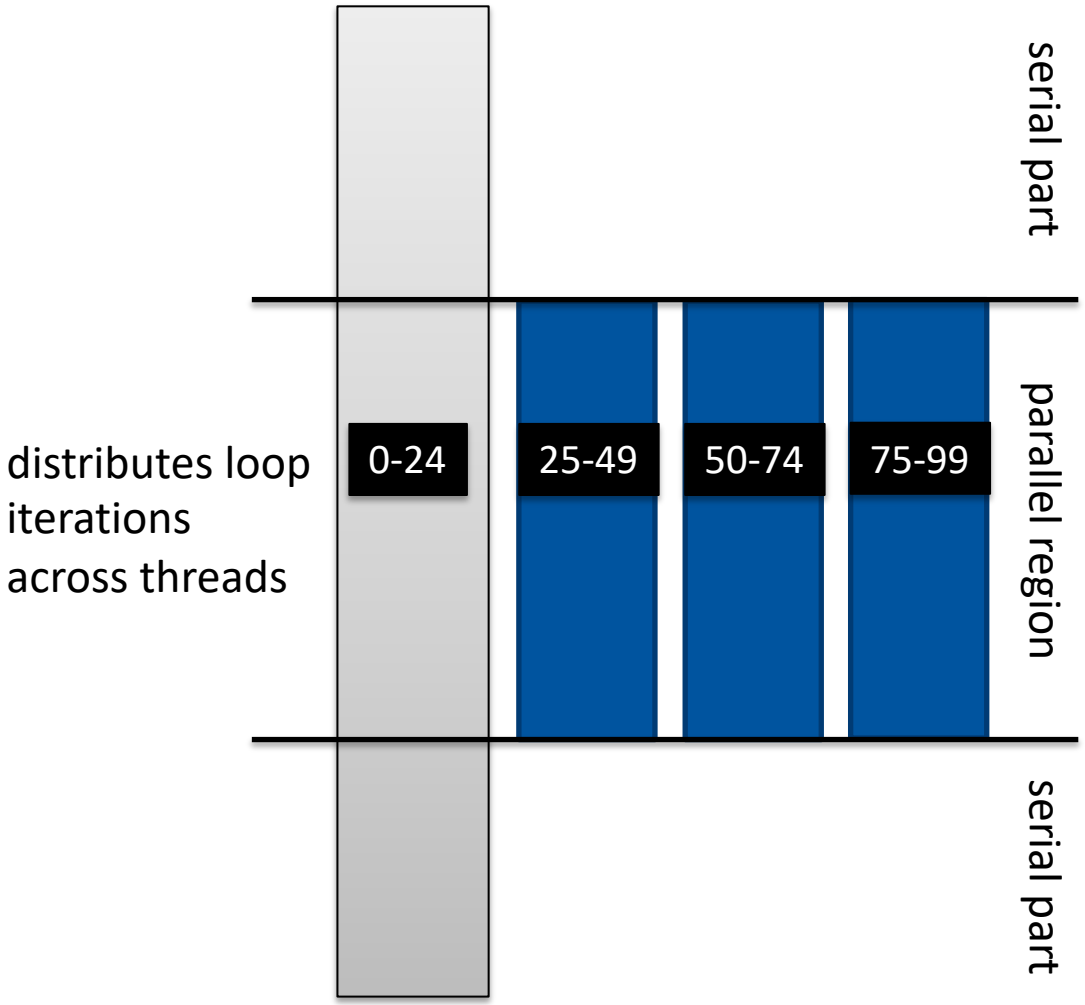
Data Sharing Attributes

```
int d=2;
.
.
#pragma omp parallel firstprivate(d)
{
#pragma omp single
{d=6;}
.
}
.
.
.
```



For Worksharing

```
.
.
.
#pragma omp parallel
#pragma omp for
for (int i=0; i<100; i++){
.
.
.
}
.
.
.
```



Parallelizable Loops

- **Loop iterations must be independent to parallelize a loop!**

No loop dependencies => parallelizable

```
#pragma omp parallel for
for ( i=0 ; i<100 ; i++ ){
        a[i] = b[i] + c[i];
}
```

Loop dependencies => **not** parallelizable

```
#pragma omp parallel for
for ( i=1 ; i<100 ; i++ ){
        a[i] = a[i] + a[i-1];
}
```

- **Simple test: If the results differ when the code is executed backwards, the loop iterations are not independent.**

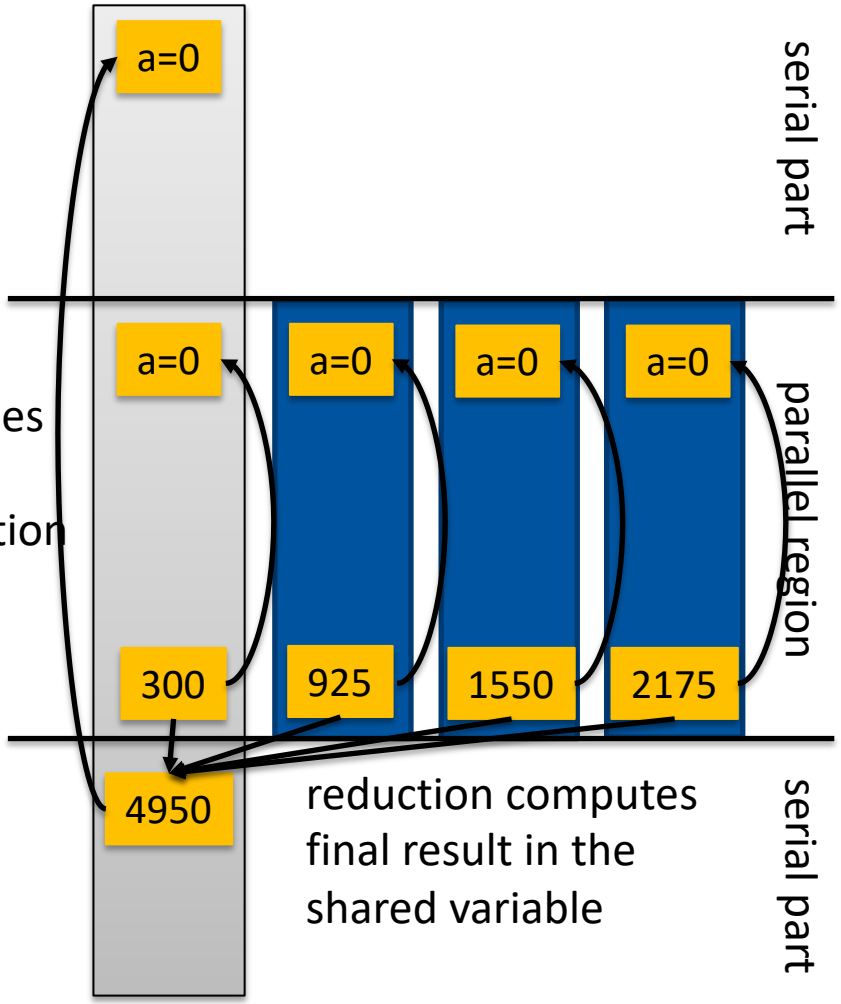
  BUT: This test alone is not sufficient

Reduction Operations

```
int a=0;
.
.
#pragma omp parallel
#pragma omp for reduction(+:a)
for (int i=0; i<100; i++)
{
        a+=i;
}
.
.
.
```

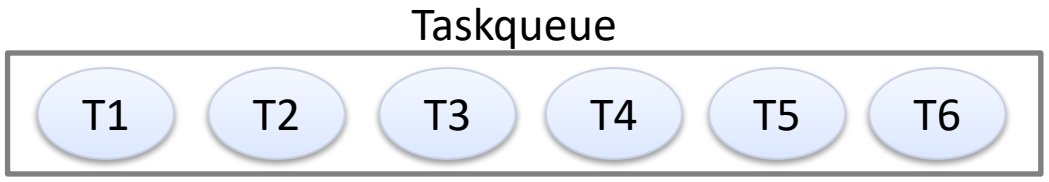
local copies for computation

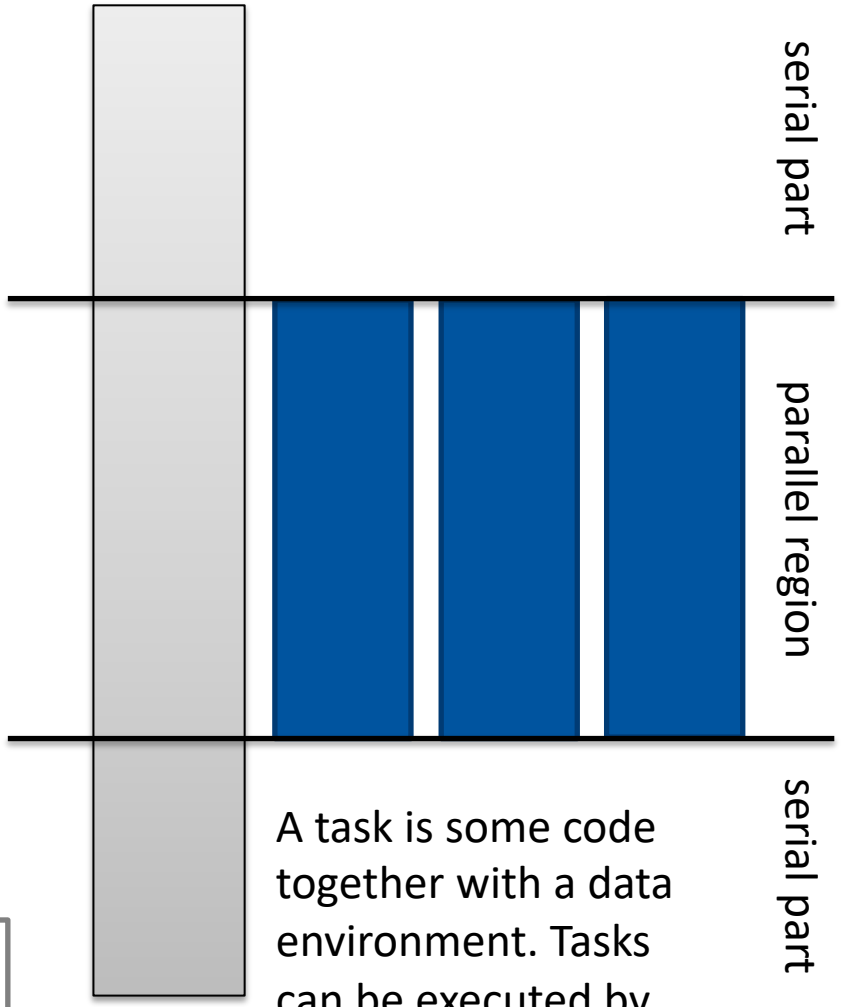
update is written to the shared variable



Tasks

```
#pragma omp parallel
#pragma omp single
while (work()){
        #pragma omp task
        {
        …
        }
}// implicit barrier here
.
.
```





A task is some code together with a data environment. Tasks can be executed by any thread in any order.

The Barrier and Taskwait Constructs

- **OpenMP `barrier` (implicit or explicit)**
  - → All tasks created by any thread of the current *Team* are guaranteed to be completed at barrier exit

```
C/C++
#pragma omp barrier
```

- **Task barrier: `taskwait`**
  - → Encountering Task suspends until child tasks are complete
    - → Only direct childs, not descendants!

```
C/C++
#pragma omp taskwait
```

Questions?