Functional (Task) Decomposition

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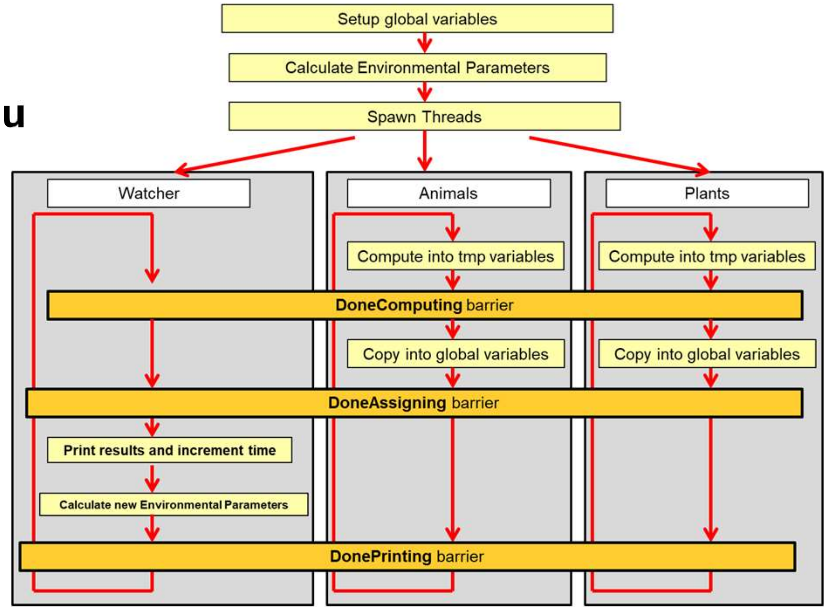


Setup global variables

Calculate Environmental Parameters

Spawn Threads

Watcher

Animals

Plants

Compute into tmp variables

Compute into tmp variables

DoneComputing barrier

Copy into global variables

Copy into global variables

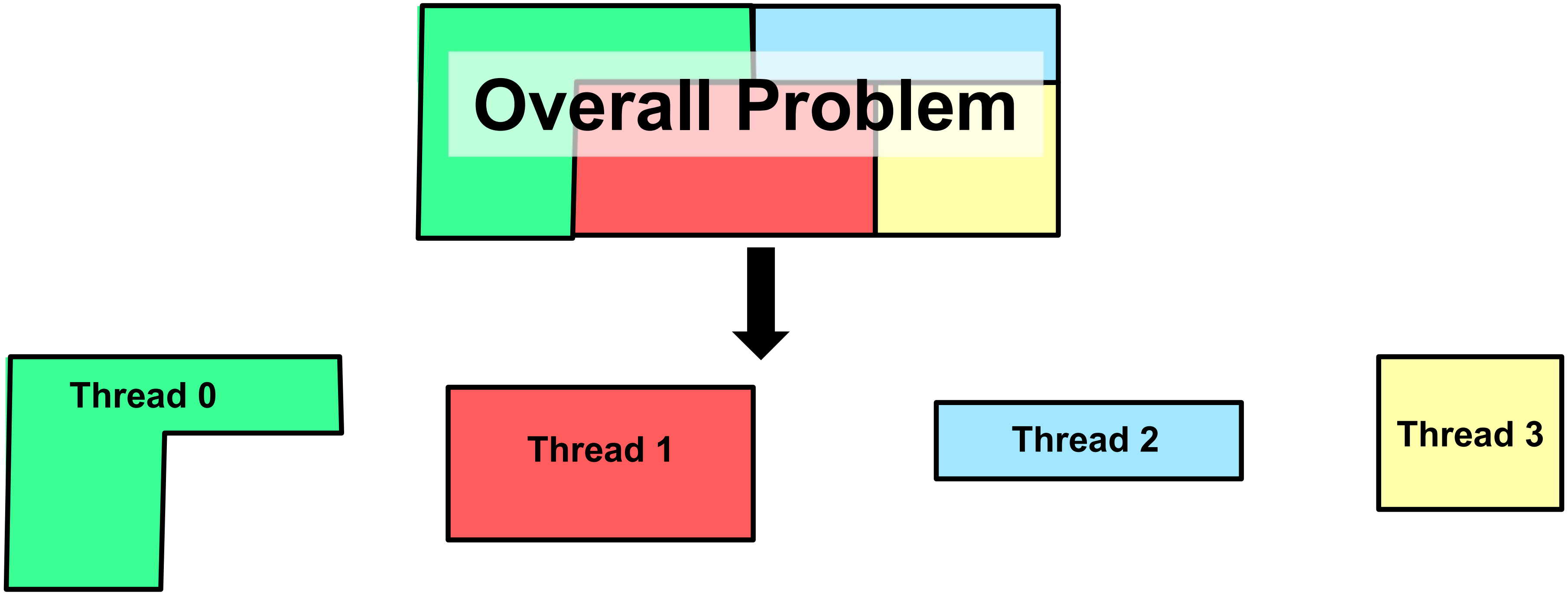
DoneAssigning barrier

Print results and increment time

Calculate new Environmental Parameters

DonePrinting barrier

The Functional (or Task) Decomposition Design Pattern



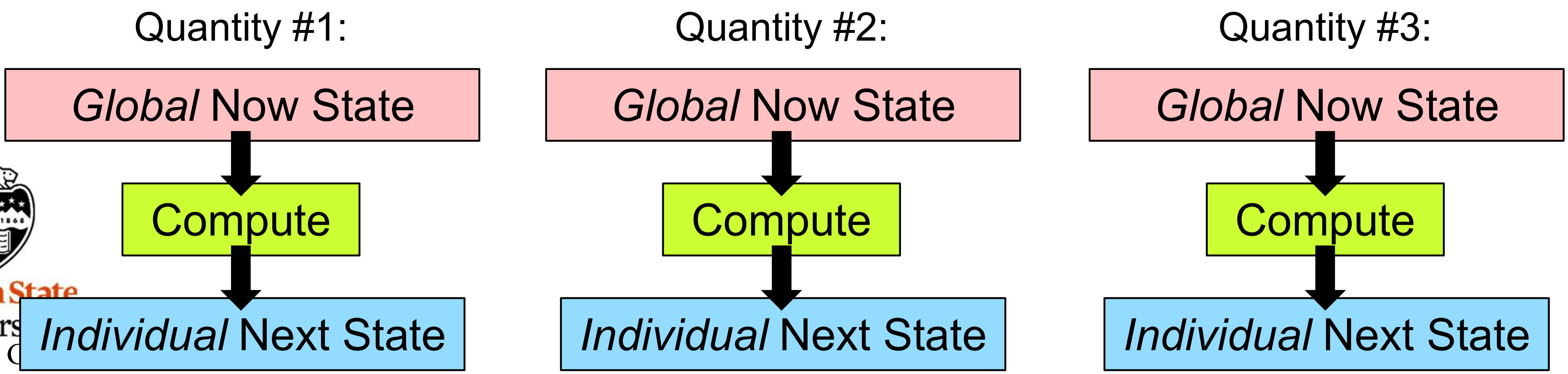
A good example of this is the computer game *SimPark*.

The Functional (or Task) Decomposition Design Pattern

Credit: Maxis (Sim Park)

How is this is different from Data Decomposition (such as the OpenMP for-loops)

- This is done less for performance and more for programming convenience.
- This is often done in simulations, where each quantity in the simulation needs to make decisions about what it does *next* based on what it and all the other global quantities are doing *right now*.
- Each quantity takes *all* of the “Now” state data and computes its own “Next” state.
- The biggest trick is to synchronize the different quantities so that each of them is seeing only what the others’ data values are *right now*. Nobody is allowed to switch their data states until they are *all* done consuming the current data and thus are ready to switch together.
- The synchronization is accomplished with barriers.



Quantity #1:

Global Now State

Compute

Individual Next State

Quantity #2:

Global Now State

Compute

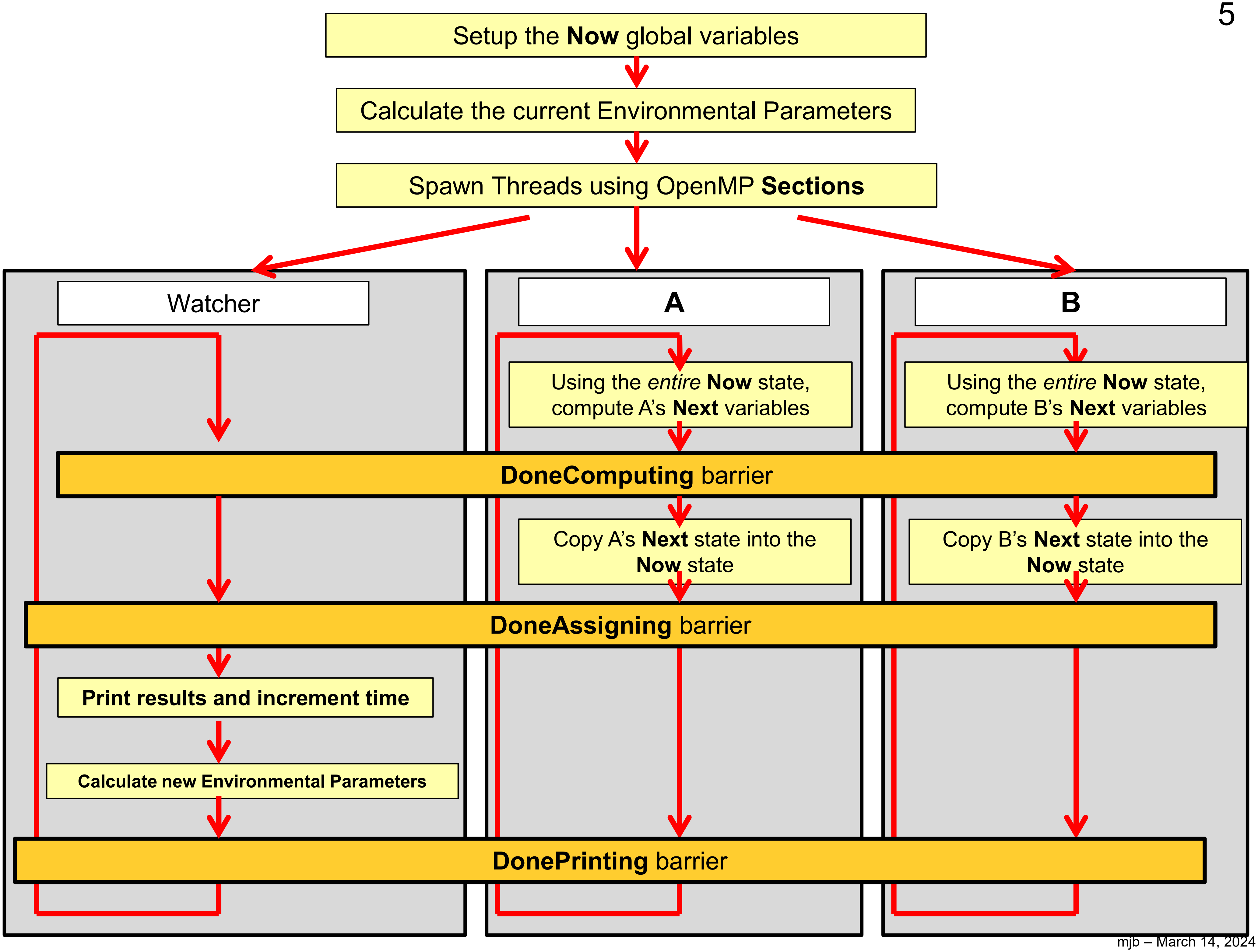
Individual Next State

Quantity #3:

Global Now State

Compute

Individual Next State



Setup the **Now** global variables

Calculate the current Environmental Parameters

Spawn Threads using OpenMP **Sections**

Watcher

A

B

Using the *entire* **Now** state, compute A’s **Next** variables

Using the *entire* **Now** state, compute B’s **Next** variables

DoneComputing barrier

Copy A’s **Next** state into the **Now** state

Copy B’s **Next** state into the **Now** state

DoneAssigning barrier

Print results and increment time

Calculate new Environmental Parameters

DonePrinting barrier

The Functional Decomposition Design Pattern

```
int
main( int argc, char *argv[ ] )
{
        . . .
        omp_set_num_threads( 3 );
        InitBarrier( 3 );                    // don't worry about this for now, we will get to this later

        #pragma omp parallel sections
        {
                #pragma omp section
                 {
                        Watcher( );
                 }

                #pragma omp section
                {
                        Animals( );
                }

                #pragma omp section
                {
                        Plants( );
                }
        }   // implied barrier -- all functions must return to get past here
}
```

The Functional Decomposition Design Pattern

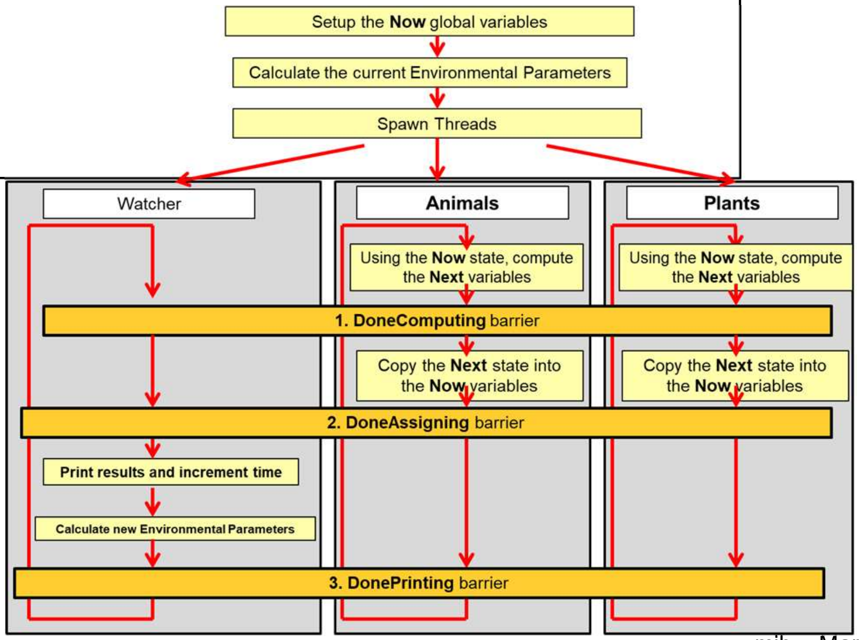
```
void
Watcher( )
{
        while( << You decide how to know when it's all finished? >> )
        {
                // do nothing
                WaitBarrier( );             // 1.

                // do nothing
                WaitBarrier( );             // 2.

                << write out the "Now" state of data >>

                << advance time and re-compute all environmental variables >>

                WaitBarrier( );             // 3.
        }
}
```



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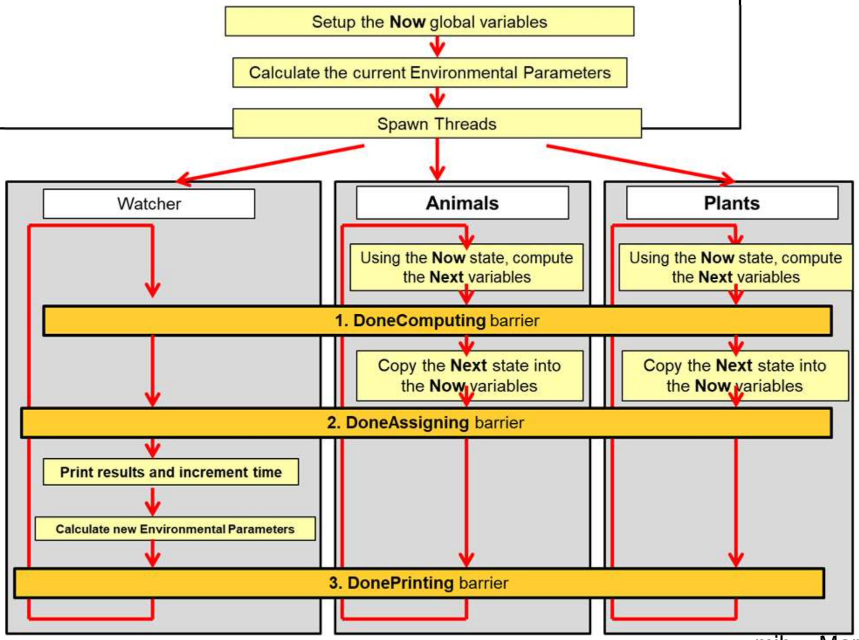
The Functional Decomposition Design Pattern

```
void
Animals( )
{
        while( << You decide how to know when it's all finished? >> )
        {
                int nextXXX= << function of what all states are right Now >>
                . . .
                WaitBarrier( );           // 1.

                NowXXX = nextXXX;         // copy the computed next state to the Now state

                WaitBarrier( );           // 2.

                 // do nothing
                 WaitBarrier( );          // 3.
         }
}
```



Setup the **Now** global variables

Calculate the current Environmental Parameters

Spawn Threads

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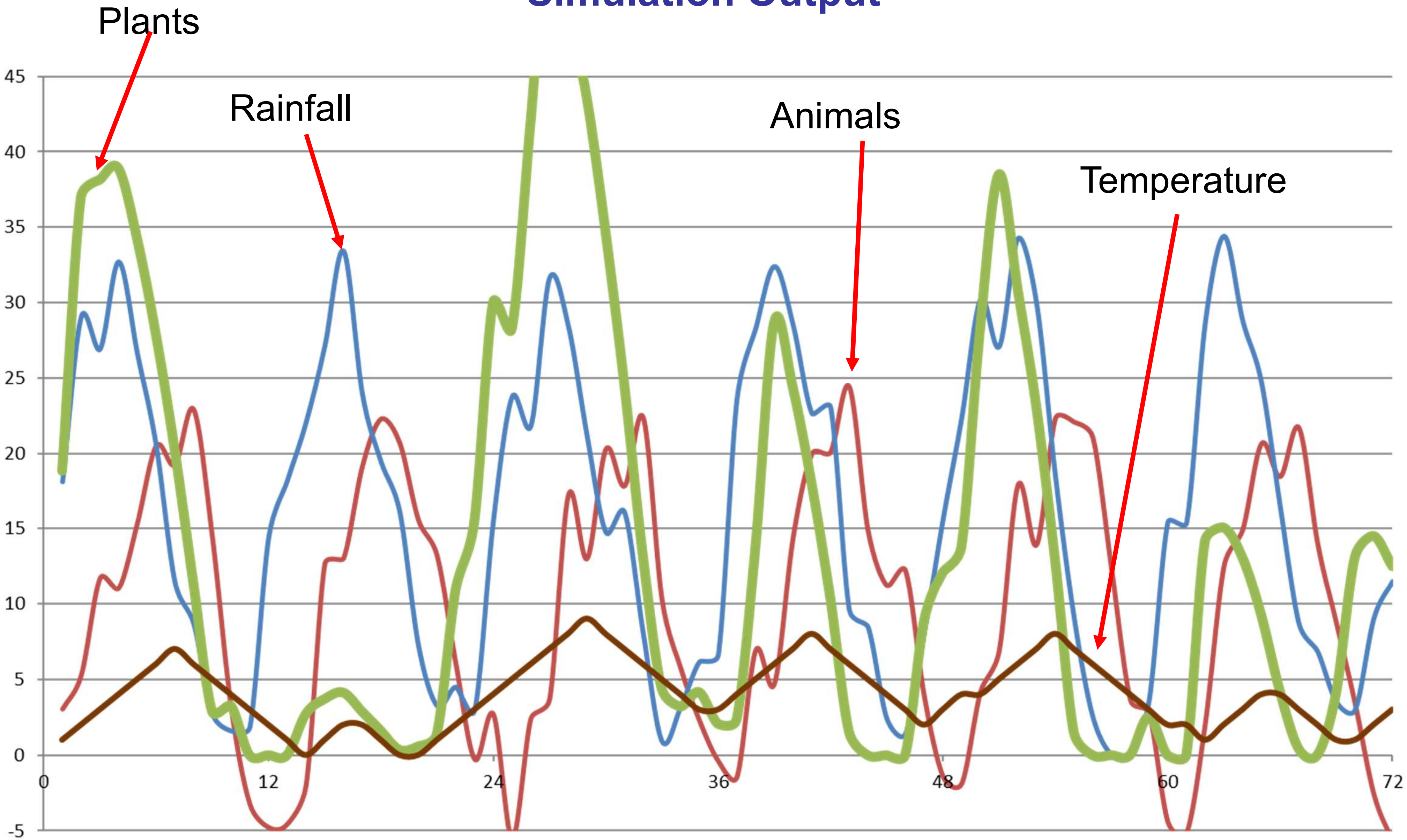
Simulation Output



Time →

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We Have to Make Our Own Barrier Function

Why can’t we just use **#pragma omp barrier** ?

Functional Decomposition is a good example of when you can’t.

There are two ways to think about how to allow a program to implement a barrier:

1. Make a thread wait at a specific address in the code. Keep waiting until *all* threads are waiting there.
2. Make a thread wait when it specifically asks to "Wait". Keep waiting until *all* threads have asked to "Wait".

Both of these sound legitimate, but:

- The OpenMP specification only allows for #1.
- The Functional Decomposition described here wants to use #2, because the waiting needs to happen at different addresses in different functions

We Have to Make Our Own Barrier Function

```
omp_lock_t      Lock;
volatile int    NumInThreadTeam;
volatile int    NumAtBarrier;
volatile int    NumGone;

void
InitBarrier( int n )
{
        NumInThreadTeam = n;                    // number of threads you want to block at the barrier
        NumAtBarrier = 0;
        omp_init_lock( &Lock );
}

void
WaitBarrier( )
{
        omp_set_lock( &Lock );
        {
                NumAtBarrier++;
                if( NumAtBarrier == NumInThreadTeam )           // release the waiting threads
                {
                        NumGone = 0;
                        NumAtBarrier = 0;
                        // let all other threads return before this one unlocks:
                        while( NumGone != NumInThreadTeam - 1 );
                        omp_unset_lock( &Lock );
                        return;
                }
        }
        omp_unset_lock( &Lock );

        while( NumAtBarrier != 0 );             // all threads wait here until the last one arrives …

        #pragma omp atomic                      // … and sets NumAtBarrier to 0
                NumGone++;
}
```

The WaitAtBarrier( ) Logic

Thread #0	Thread #1	Thread #2	NumInThreadTeam	NumAtBarrier	NumGone
			3	0	
Calls WaitBarrier( )			3	0	
Sets the lock			3	0	
Increments NumAtBarrier			3	1	
NumAtBarrier != NumInThreadTeam			3	1	
Unsets the lock			3	1	
Stuck at while-loop #2			3	1	
	Calls WaitBarrier( )		3	1	
	Sets the lock		3	1	
	Increments NumAtBarrier		3	2	
	NumAtBarrier != NumInThreadTeam		3	2	
	Unsets the lock		3	2	
	Stuck at while-loop #2		3	2	
		Calls WaitBarrier( )	3	2	
		Sets the lock	3	2	
		Increments NumAtBarrier	3	3	
		NumAtBarrier == NumInThreadTeam	3	3	
		Sets NumGone	3	3	0
		Sets NumAtBarrier	3	0	0
		Stuck at while-loop #1	3	0	0
Falls through while-loop #2			3	0	0
Increments NumGone			3	0	1
Returns			3	0	1
	Falls through while-loop #2		3	0	2
	Increments NumGone		3	0	2
	Returns		3	0	2
		Falls through while-loop #1	3	0	2
		Unsets the lock	3	0	2
		Returns	3	0	2