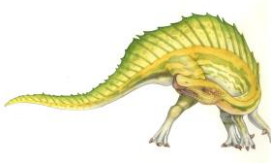
Monitors

- A high-level abstraction that provides a convenient and effective mechanism for process synchronization
- *Abstract data type*, internal variables only accessible by code within the procedure
- Only one process may be active within the monitor at a time
- But not powerful enough to model some synchronization schemes

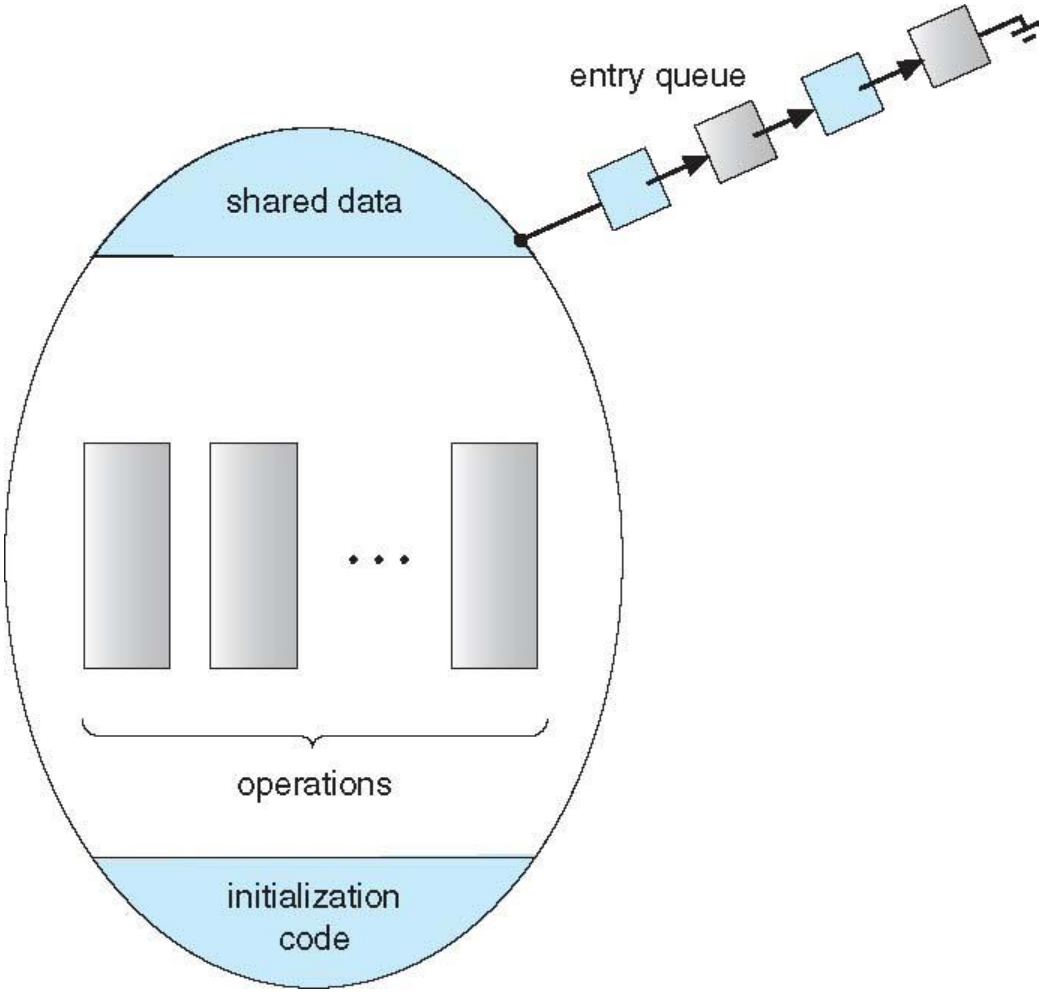
```
monitor monitor-name
{
  // shared variable declarations
  procedure P1 (…) { …. }

  procedure Pn (…) {……}

    Initialization code (…) { … }
  }
}
```

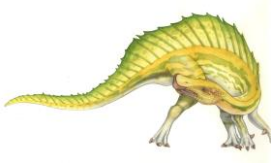


Schematic view of a Monitor

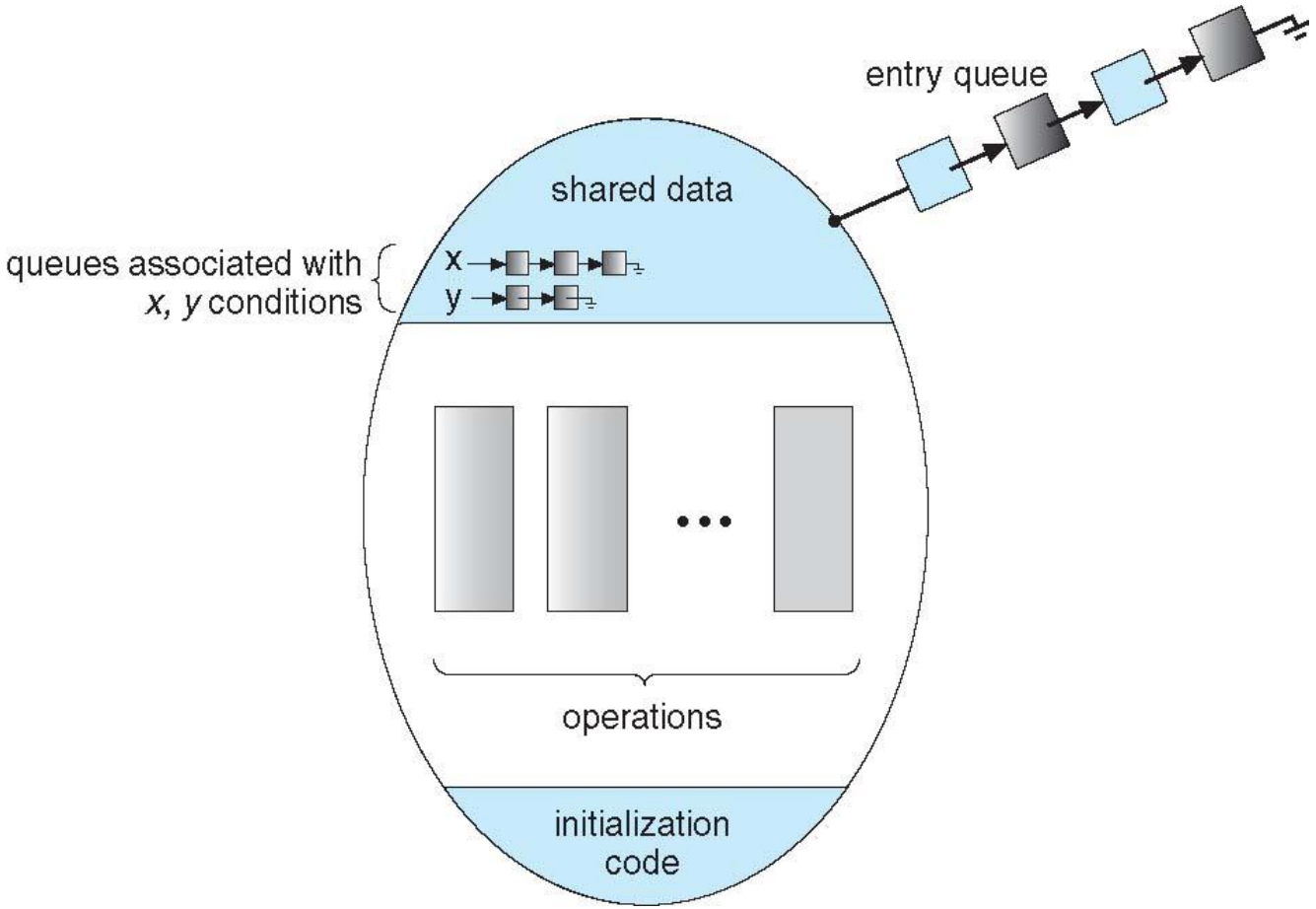


Condition Variables

- **`condition x, y;`**
- Two operations are allowed on a condition variable:
  - **`x.wait()`** – a process that invokes the operation is suspended until **`x.signal()`**
  - **`x.signal()`** – resumes one of processes (if any) that invoked **`x.wait()`**
    - If no **`x.wait()`** on the variable, then it has no effect on the variable



Monitor with Condition Variables



Condition Variables Choices

- If process P invokes **`x.signal()`**, and process Q is suspended in **`x.wait()`**, what should happen next?
  - Both Q and P cannot execute in paralel. If Q is resumed, then P must wait
- Options include
  - **Signal and wait** – P waits until Q either leaves the monitor or it waits for another condition
  - **Signal and continue** – Q waits until P either leaves the monitor or it waits for another condition
  - Both have pros and cons – language implementer can decide
  - Monitors implemented in Concurrent Pascal compromise
    - P executing signal immediately leaves the monitor, Q is resumed
  - Implemented in other languages including Mesa, C#, Java

Monitor Solution to Dining Philosophers

```
monitor DiningPhilosophers
{
   enum { THINKING; HUNGRY, EATING) state [5] ;
   condition self [5];

   void pickup (int i) {
          state[i] = HUNGRY;
          test(i);
          if (state[i] != EATING) self[i].wait;
}

   void putdown (int i) {
          state[i] = THINKING;
                  // test left and right neighbors
           test((i + 4) % 5);
           test((i + 1) % 5);
}
```

Solution to Dining Philosophers (Cont.)

```
    void test (int i) {
            if ((state[(i + 4) % 5] != EATING) &&
            (state[i] == HUNGRY) &&
            (state[(i + 1) % 5] != EATING) ) {
                state[i] = EATING ;
             self[i].signal () ;
            }
    }

        initialization_code() {
           for (int i = 0; i < 5; i++)
           state[i] = THINKING;
         }
}
```

Solution to Dining Philosophers (Cont.)

- Each philosopher *i* invokes the operations **`pickup()`** and **`putdown()`** in the following sequence:

```
DiningPhilosophers.pickup(i);

    EAT

DiningPhilosophers.putdown(i);
```

- No deadlock, but starvation is possible