Algorithm 3

- Think of this algorithm as using a referee who keeps track of whose "turn" it is
  - Anytime the two disagree about whose turn it is, they ask the referee, who keeps track of whose turn it is to have priority
  - This is called Peterson's algorithm (1981)
    - The original (but more complicated) solution to this problem is Dekker's algorithm (1965)
- For n processes, we can use Lamport's Bakery algorithm (1974)
  - When a thread tries to enter the critical section, it get assigned a number higher than anyone else's number
  - Thread with lowest number gets in
  - If two threads get the same number, the one with the lowest process id gets in

Algorithm 3 (cont.)

- Code:

```
t1 ( )   {
     while (true)   {
          t1_in_crit = true;
          turn = 2;
          while (t2_in_crit == true && turn != 1)
               ;    /* do nothing */
          … critical section of code …
           t1_in_crit = false;
          … other non-critical code …
     }
}

t2 ( )   {
     while (true)   {
          similar…
     }
}
```


Semaphores — OS Support for Mutual Exclusion

- Semaphores were invented by Dijkstra in 1965, and can be thought of as a generalized locking mechanism
  - A semaphore supports two **atomic** operations, **P / wait** and **V / signal**
    - The semaphore initialized to 1
    - Before entering the critical section, a thread calls "**P(semaphore)**", or sometimes "**wait(semaphore)**"
    - After leaving the critical section, a thread calls "**V(semaphore)**", or sometimes "**signal(semaphore)**"
- Too much milk:

Thread A	Thread B

milk.P( );
if (noMilk)
    buy milk;
milk.V( );
	milk.P( );
	if (noMilk)
	    buy milk;
	milk.V( );

What Does a Semaphore Do?

- Semaphore "s" is initially 1
- Before entering the critical section, a thread calls "**P(s)**" or "**wait(s)**"
  - wait (s):
    - s = s – 1
    - if (s < 0)

      block the thread that called wait(s) on a queue associated with semaphore s
    - otherwise

      let the thread that called wait(s) continue into the critical section
- After leaving the critical section, a thread calls "**V(s)**" or "**signal(s)**"
  - signal (s):
    - s = s + 1
    - if (s ≤ 0), then

      wake up one of the threads that called wait(s), and run it so that it can continue into the critical section

Using Semaphores for Mutual Exclusion

- Too much milk:

Thread A	Thread B
milk.P( );	milk.P( );
if (!haveMilk)	if (!haveMilk)
buy milk;	buy milk;
haveMilk=true;	haveMilk=true;
milk.V( );	milk.V( );

  - "haveMilk" is a Boolean variable
  - "milk" is a semaphore initialized to 1

- Execution:

After:	milk	queue	A	B
	1			
A: milk.P( );	0		in CS	
B: milk.P( );	-1	B	in CS	waiting
A: milk.V( );	0		finish	ready, in CS
B: milk.V( );	1			finish

Semaphore Operation

- Informal description:
  - Single igloo, containing a blackboard and a very large freezer
  - Wait — thread enters the igloo, checks the blackboard, and decrements the value shown there
    - If new value is 0, thread goes on to the critical section
    - If new value is negative, thread crawls in the freezer and hibernates (making room for others to enter the igloo)
  - Signal — thread enters igloo, checks blackboard, and increments the value there
    - If new value is 0 or negative, there's a thread waiting in the freezer, so it thaws out a frozen thread, which then goes on to the critical section

Using Semaphores

- Code using semaphores:

```
t1 ( )   {
    while (true)   {
        wait (s);
        … critical section of code …
        signal (s);
        … other non-critical code …
    }
}

t2 ( )   {
    while (true)   {
        wait (s);
        … critical section of code …
        signal (s);
        … other non-critical code …
    }
}
```


Semaphore Operation & Values

- Semaphores (simplified slightly):

wait (s):	signal (s):
s = s – 1	s = s + 1
if (s < 0)	if (s ≤ 0)
block the thread that called wait(s)	wake up & run one of the waiting threads
otherwise	
continue into CS	

- Semaphore values:
  - *Binary semaphore* has an initial value of 1 and is used for *mutual exclusion*
    - Positive semaphore = number of (additional) threads that can be allowed into the critical section (usually max of 1)
    - Negative semaphore = number of threads blocked (note — there's also one in CS)
  - *Counting semaphore* has an initial value greater than 1, and is used for *synchronization* between threads

The Coke Machine (Bounded-Buffer Producer-Consumer)

```
/* number of full slots (Cokes) in machine */
semaphore fullSlot = 0;
/* number of empty slots in machine */
semaphore emptySlot = 100;
/* only one person accesses machine at a time */
semaphore mutex = 1;

DeliveryPerson()
{
    emptySlot.P( );      /* empty slot avail? */
    mutex.P( );          /* exclusive access */
    put 1 Coke in machine
    mutex.V( );
    fullSlot.V( );       /* another full slot! */
}

ThirstyPerson()
{
    fullSlot.P( );       /* full slot (Coke)? */
    mutex.P( );          /* exclusive access */
    get 1 Coke from machine
    mutex.V( );
    emptySlot.V( );      /* another empty slot! */
}
```