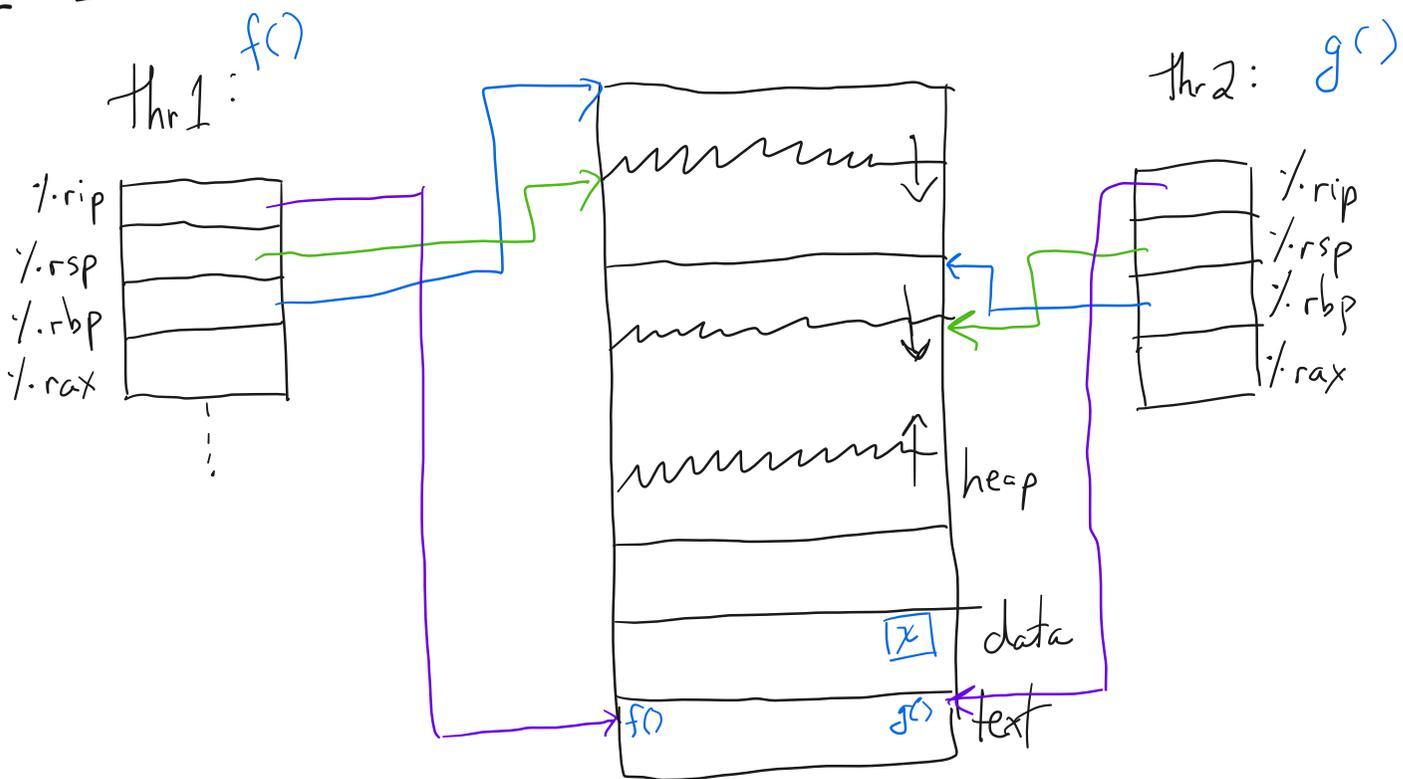


- 1. Last time
- 2. Intro to concurrency, continued
- 3. Managing concurrency
- 4. Mutexes
- 5. Condition variables
- 6. Semaphores

2. Intro to concurrency

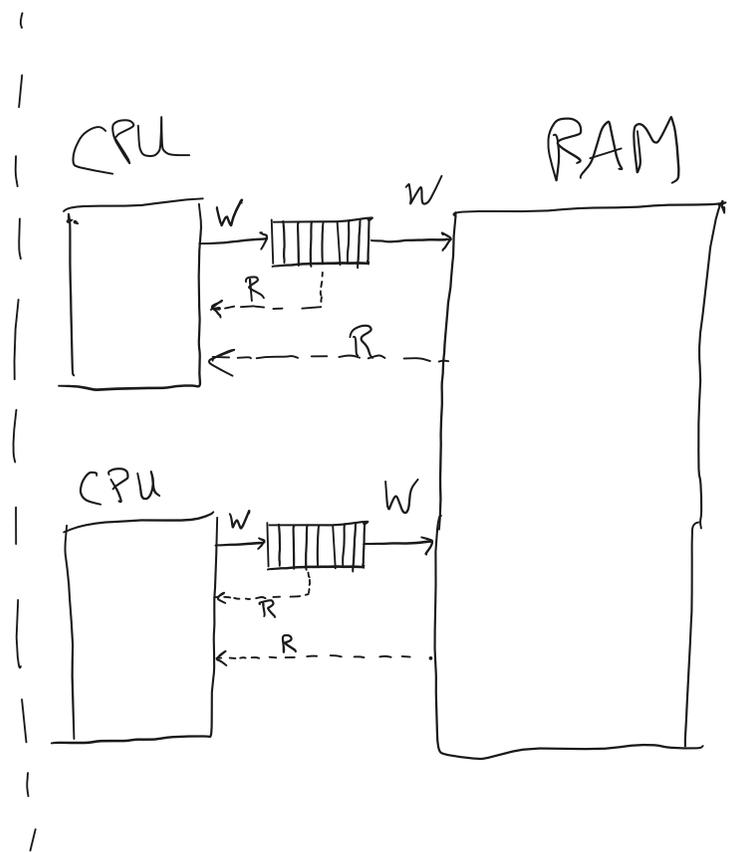
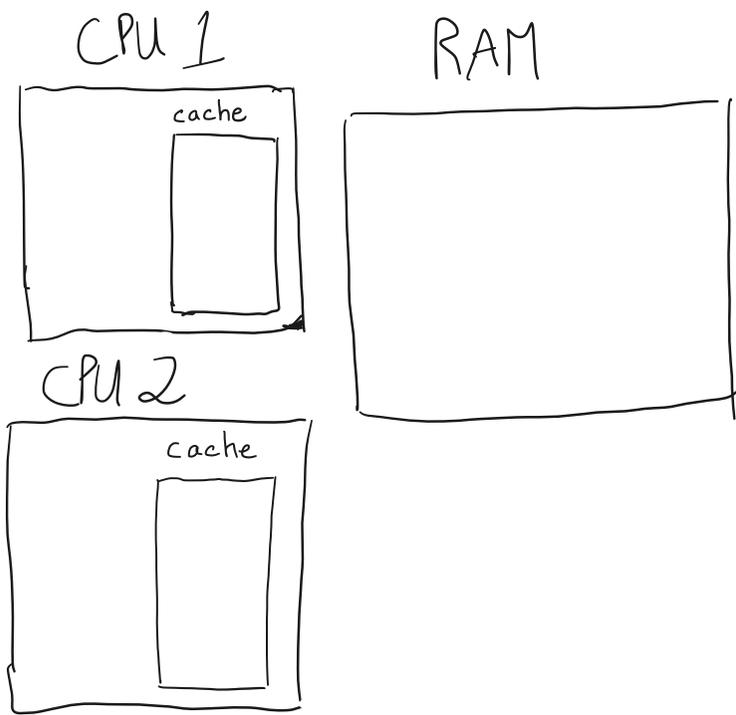
- panels 1-3 on handout 03: all examples of "race conditions" (uncontrolled access to shared memory)
- hardware makes the problem harder (see panel 4)



Threads share memory, but they have their own "execution context" (registers and stack).

To the programmer, it "feels like" multiple things are happening at once in the program.

memory consistency



3. Managing concurrency

a. Critical sections: the concept: "protect from concurrent execution".

- i. mutual exclusion
- ii. progress
- iii. bounded waiting

b. Protecting critical sections

lock() / unlock()

enter() / leave()

acquire() / release()

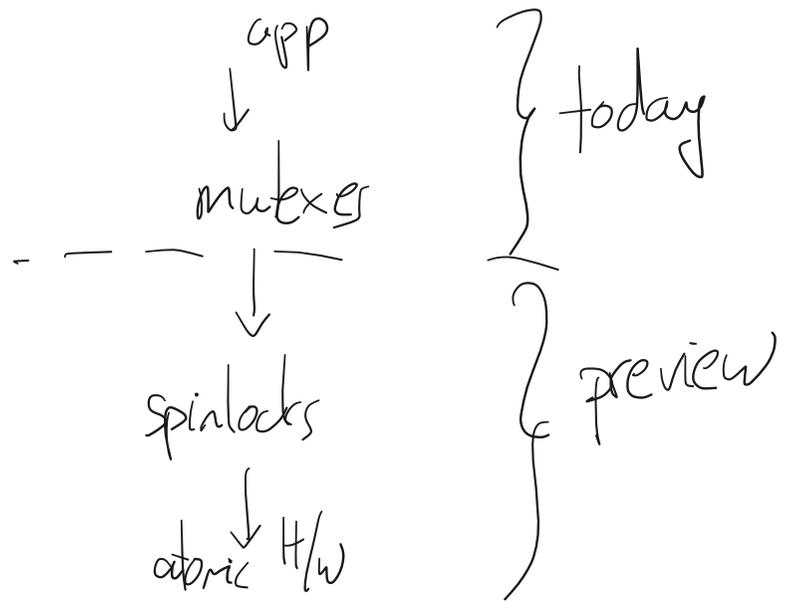
Implementing critical sections

c. Implementing critical sections

(i) single-CPU machine: `enter()` → disable interrupts

`leave()` → enable interrupts

4. Mutexes



5. Condition variables

`cond_int (Cond*, --);`

`cond_wait (Mutex* m, Cond*);`

`cond_signal (Mutex* m, Cond*);`

`cond_broadcast (Mutex* m, Cond*);`

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handout04.txt

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```

1 CS 202
2 Handout 4 (Class 5)
3
4 The handout from the last class gave examples of race conditions. The following
5 panels demonstrate the use of concurrency primitives (mutexes, etc.). We are
6 using concurrency primitives to eliminate race conditions (see items 1
7 and 2a) and improve scheduling (see item 2b).

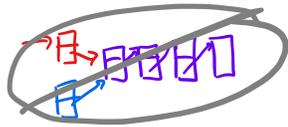
```

1. Protecting the linked list.....

```

10
11     Mutex list_mutex;
12
13     insert(int data) {
14         List_elem* l = new List_elem;
15         l->data = data;
16
17         acquire(&list_mutex);
18
19         l->next = head;
20         head = l;
21
22         release(&list_mutex);
23     }
24

```



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```

25 2. Producer/consumer revisited [also known as bounded buffer]
26

```

2a. Producer/consumer [bounded buffer] with mutexes

```

27
28     Mutex mutex;
29
30     void producer (void *ignored) {
31         for (;;) {
32             /* next line produces an item and puts it in nextProduced */
33             nextProduced = means_of_production();
34
35             acquire(&mutex);
36             while (count == BUFFER_SIZE) {
37                 release(&mutex);
38                 yield(); /* or schedule() */
39                 acquire(&mutex);
40             }
41
42             buffer [in] = nextProduced;
43             in = (in + 1) % BUFFER_SIZE;
44             count++;
45             release(&mutex);
46         }
47     }
48
49     void consumer (void *ignored) {
50         for (;;) {
51
52             acquire(&mutex);
53             while (count == 0) {
54                 release(&mutex);
55                 yield(); /* or schedule() */
56                 acquire(&mutex);
57             }
58
59             nextConsumed = buffer[out];
60             out = (out + 1) % BUFFER_SIZE;
61             count--;
62             release(&mutex);
63
64             /* next line abstractly consumes the item */
65             consume_item(nextConsumed);
66         }
67     }
68
69

```

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```

70
71 2b. Producer/consumer [bounded buffer] with mutexes and condition variables
72
73     Mutex mutex;
74     Cond nonempty;
75     Cond nonfull;
76
77     void producer (void *ignored) {
78         for (;;) {
79             /* next line produces an item and puts it in nextProduced */
80             nextProduced = means_of_production();
81
82             acquire(&mutex);
83             while (count == BUFFER_SIZE)
84                 cond_wait(&nonfull, &mutex);
85
86             buffer [in] = nextProduced;
87             in = (in + 1) % BUFFER_SIZE;
88             count++;
89             cond_signal(&nonempty, &mutex);
90             release(&mutex);
91         }
92     }
93
94     void consumer (void *ignored) {
95         for (;;) {
96
97             acquire(&mutex);
98             while (count == 0)
99                 cond_wait(&nonempty, &mutex);
100
101             nextConsumed = buffer[out];
102             out = (out + 1) % BUFFER_SIZE;
103             count--;
104             cond_signal(&nonfull, &mutex);
105             release(&mutex);
106
107             /* next line abstractly consumes the item */
108             consume_item(nextConsumed);
109         }
110     }
111
112     Question: why does cond_wait need to both release the mutex and
113     sleep? Why not:
114
115         while (count == BUFFER_SIZE) {
116             release(&mutex);
117             cond_wait(&nonfull);
118             acquire(&mutex);
119         }
120
121

```

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```

122 2c. Producer/consumer [bounded buffer] with semaphores
123
124     Semaphore mutex(1);          /* mutex initialized to 1 */
125     Semaphore empty(BUFFER_SIZE); /* start with BUFFER_SIZE empty slots */
126     Semaphore full(0);          /* 0 full slots */
127
128     void producer (void *ignored) {
129         for (;;) {
130             /* next line produces an item and puts it in nextProduced */
131             nextProduced = means_of_production();
132
133             /*
134              * next line diminishes the count of empty slots and
135              * waits if there are no empty slots
136              */
137             sem_down(&empty);
138             sem_down(&mutex); /* get exclusive access */
139
140             buffer [in] = nextProduced;
141             in = (in + 1) % BUFFER_SIZE;
142
143             sem_up(&mutex);
144             sem_up(&full); /* we just increased the # of full slots */
145         }
146     }
147
148     void consumer (void *ignored) {
149         for (;;) {
150
151             /*
152              * next line diminishes the count of full slots and
153              * waits if there are no full slots
154              */
155             sem_down(&full);
156             sem_down(&mutex);
157
158             nextConsumed = buffer[out];
159             out = (out + 1) % BUFFER_SIZE;
160
161             sem_up(&mutex);
162             sem_up(&empty); /* one further empty slot */
163
164             /* next line abstractly consumes the item */
165             consume_item(nextConsumed);
166         }
167     }
168
169     Semaphores *can* (not always) lead to elegant solutions (notice
170     that the code above is fewer lines than 2b) but they are much
171     harder to use.
172
173     The fundamental issue is that semaphores make implicit (counts,
174     conditions, etc.) what is probably best left explicit. Moreover,
175     they *also* implement mutual exclusion.
176
177     For this reason, you should not use semaphores. This example is
178     here mainly for completeness and so you know what a semaphore
179     is. But do not code with them. Solutions that use semaphores in
180     this course will receive no credit.

```