CS1110 16 April 2010
while loops

Reading: today: Ch. 7 and ProgramLive sections.

For next time: Ch. 8.1-8.3

Prelim 2. Thursday evening, 7:30PM

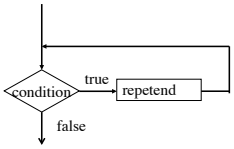
Watch the lectures on www.videonote.com/cornell

Beyond ranges of integers: the while loop

while (*<condition>*) {
  sequence of declarations and statements
}

<condition>: a boolean expression.

<repetend>: sequence of statements.



In comparison to for-loops: we get a broader notion of "there's still stuff to do" (not tied to integer ranges), but *we* must ensure that "condition" stops holding (since there's no explicit increment).

Canonical while loops

```
// Process b..c
for (int k= b; k <= c; k= k+1) {
    Process k;
}
```

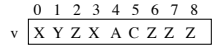
scope of k: the loop; k can't be used after the loop

```
// Process b..c
int k= b;
while (k <= c) {
    Process k;
    k= k+1;
}
```

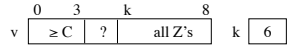
Here's one way to use the while loop

```
// process a sequence of input not of fixed size
<initialization>;
while (<still input left>) {
    Process next piece of input;
    make ready for the next piece of input;
}
```

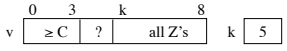

Understanding assertions about lists

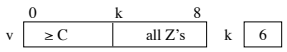


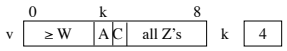
This is a list of Characters



This is an assertion about v and k. It is **true** because chars of v[0..3] are greater than 'C' and chars of v[6..8] are 'Z's.







Indicate whether each of these 3 assertions is true or false.

Linear search. Character c is in String s. Find its first position.

```
// Store in k to truthify diagram R
k= 0;
// See diagram P, below
while (    s.charAt(k) != c    ) {
    k= k + 1;
}
```

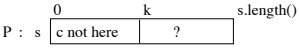
Idea: Start at beginning of s, looking for c; stop when found. How to express as an invariant?

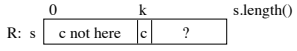
1. How does it start? ((how) does init. make inv true?)

2. When does it stop? (From the invariant and the falsity of loop condition, deduce that result holds.)

3. (How) does it make progress toward termination?

4. How does repetend keep invariant true?





The while loop: 4 loopy questions. Allows us to focus on one thing at a time and thus separate our concerns.

```
// Set c to the number of 'e's in String s.
int n= s.length();
k= 0; c= 0;
//  inv: c = #. of 'e's in s[0..k-1]
while (k < n) {
    if (s.charAt(k) == 'e')
        c= c + 1;
    k= k+ 1;
}
// c = number of 'e's in s[0..n-1]
```

1. How does it start? ((how) does init. make inv true?)

2. When does it stop? (From the invariant and the falsity of loop condition, deduce that result holds.)

3. (How) does it make progress toward termination?

4. How does repetend keep invariant true?

Suppose we are thinking of this while loop:

```
initialization;
while ( B ) {
   repetend
}
```

We add the postcondition and also show where the invariant must be true:

```
initialization;
// invariant: P
while ( B ) {
   // { P and B}
   repetend
  // { P }
}
// { P and !B }
// { Result R }
```

The four loopy questions

Second box helps us develop four loopy questions for developing or understanding a loop:

1. How does loop start? Initialization must truthify invariant P.

2. When does loop stop?

At end, P and !B are true, and these must imply R. Find !B that satisfies
P && !B => R.

3. Make progress toward termination? Put something in repetend to ensure this.

4. How to keep invariant true? Put something in repetend to ensure this.

Appendix examples: Develop loop to store in x the sum of 1..100.

We'll keep this definition of x and k true:
x = sum of 1..k–1

1. How should the loop start? Make range 1..k–1 empty: **k= 1; x= 0;**

2. When can loop stop? What condition lets us know that x has desired result? When **k == 101**

3. How can repetend make progress toward termination? **k= k+1;**

4. How do we keep def of x and k true? **x= x + k;**

Four loopy questions

```
k= 1;  x= 0;
// invariant: x = sum of 1..(k–1)
while ( k != 101) {
    x=  x + k;
    k= k + 1;
}
// { x = sum of 1..100 }
```


Building a fair coin from an unfair coin

```
/** = result of flipping a fair coin
      (heads/tails is true/false) */
public static boolean fairFlip() {
    boolean f1= new unfair flip;
    boolean f2= new unfair flip;
    /* invariant P: f1, f2 contain results
                 of 2 unfair flips, and
       in all previous flips, f1 and f2
       were the same */
     while (f1 == f2) {
         f1= new unfair flip;
         f2= new unfair flip;
     }
    // R: P  and  f1 !=  f2
    return !f1   &&   f2
}
```

John von Neumann: building a "fair coin" from an unfair coin

loopy questions:

1. P is true initially
2. When it stops, R is true
4. Repetend keeps P true
3. But we can't prove that the loop makes progress toward termination!

Can't get something for nothing

Unfair flip produces heads with some probability p, 0 < p < 1

Roach infestation

```
/** = number of weeks it takes roaches to fill the apartment --see p 244 of text*/
public static int roaches() {
    double roachVol= .001;    // Space one roach takes
    double aptVol= 20*20*8;  // Apartment volume
    double growthRate= 1.25; // Population growth rate per week

    int w=   0   ;      // number of weeks
    int pop= 100;       // roach population after w weeks

    // inv: pop = roach population after w weeks   AND
    //       before week w, volume of roaches < aptVol
    while ( aptVol > pop * roachVol) {
       pop= (int) (pop *(1 + growthRate));
       w= w + 1;
    }
    // Apartment is filled, for the first time, at week w.
    return w;
}
```


Iterative version of logarithmic algorithm to calculate b**c (we've seen a recursive version before).

```
/** set z to b**c, given c ≥ 0 */
int x= b; int y= c; int z= 1;
// invariant:  z * x**y = b**c  and 0 ≤ y ≤ c
while (y != 0) {
    if (y % 2 == 0)
          { x= x * x; y= y/2;  }
    else { z= z * x; y= y – 1; }
}
// { z = b**c }
```


Calculate quotient and remainder when dividing x by y

x/y = q + r/y **21/4= 4 + 3/4**

Property: x = q * y + r and 0 ≤ r < y

```
/** Set q to quotient  and r to remainder.
    Note: x >= 0 and y > 0 */
int q= 0; int r= x;
// invariant:  x = q * y + r    and 0 ≤ r
while (r >= y) {
        r= r – y;
        q= q + 1;
}
// { x = q * y + r    and   0 ≤ r < y }
```