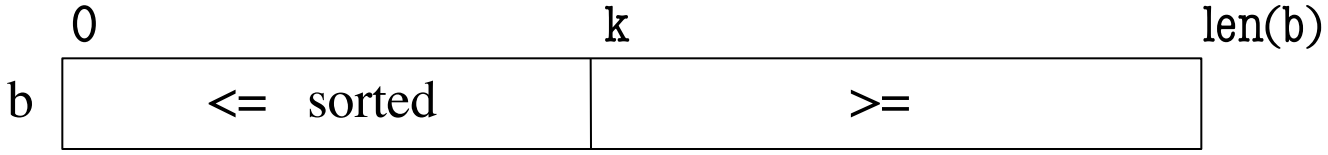
Review 7

Sequence Algorithms

Three Types of Questions

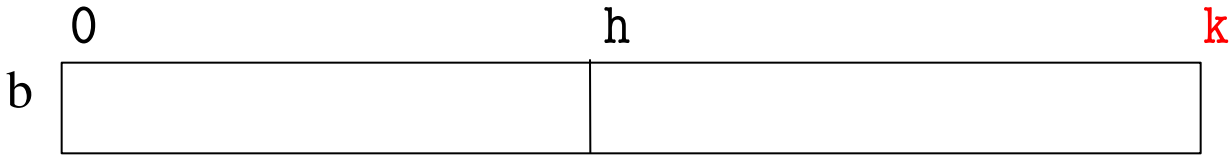
- Write body of a loop to satisfy a given invariant.
  - Problem 6, Spring 2014 (Final)
- Given an invariant with code, identify all errors.
  - Problem 6, Spring 2014 (Prelim 2)
  - Problem 6, Spring 2013 (Final)
- Given an example, rewrite it with new invariant.
  - Problem 8, Fall 2014 (Final)
  - Problem 7, Fall 2018 (Final)

Horizontal Notation for Sequences



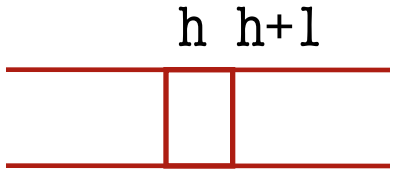
Example of an assertion about an sequence b. It asserts that:

1. b[0..k–1] is sorted (i.e. its values are in ascending order)
2. Everything in b[0..k–1] is ≤ everything in b[k..len(b)–1]



Given index h of the first element of a segment and index k of the element that follows that segment, the number of values in the segment is k – h.

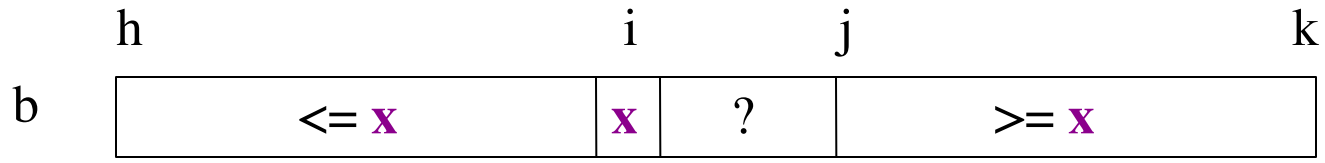
b[h .. k – 1] has k – h elements in it.



(h+1) – h = 1

DOs and DON'Ts #3

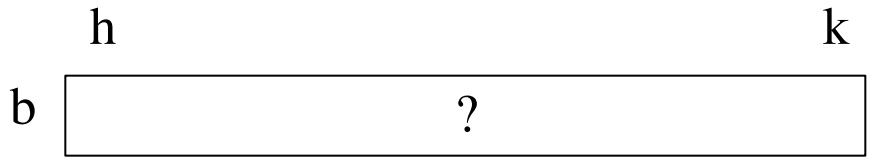
- DON'T put variables directly above vertical line.



  - Where is j?
  - Is it unknown or >= x?

Algorithm Inputs

- We may specify that the list in the algorithm is
  - b[0..len(b)-1] or
  - a segment b[h..k] or
  - a segment b[m..n-1]
- **Work with whatever is given!**

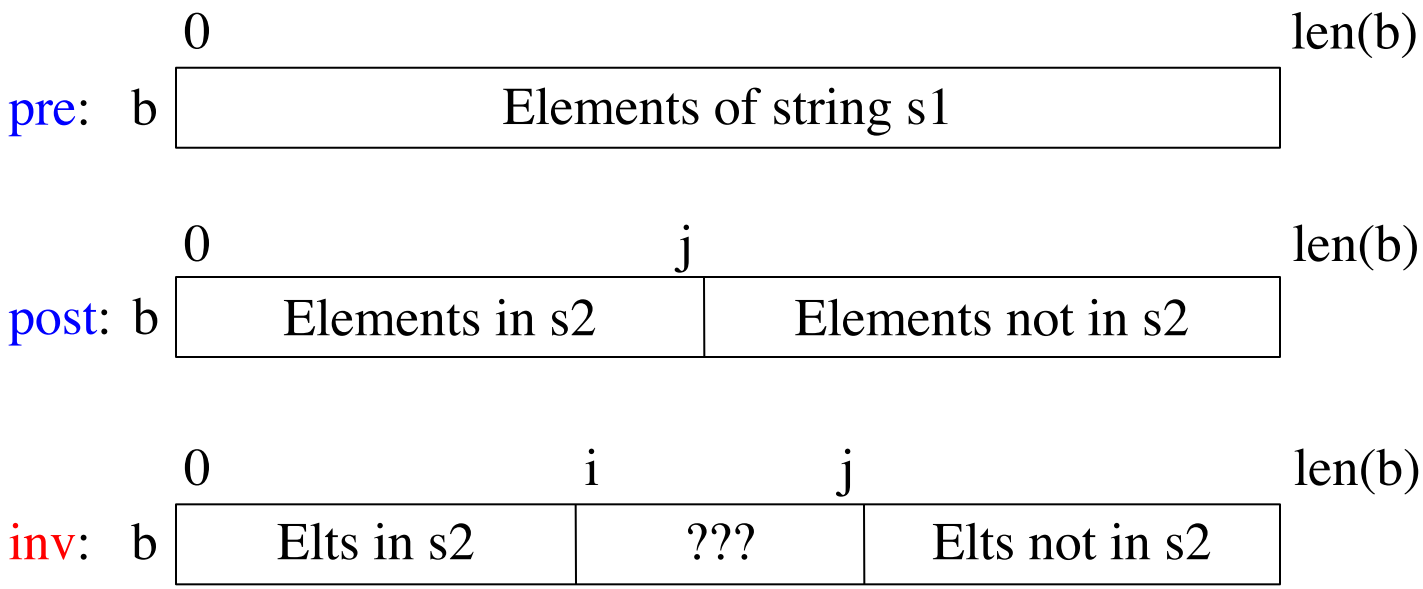


- Remember formula for # of values in an array segment
  - Following – First
  - e.g. the number of values in b[h..k] is k+1–h.

Three Types of Questions

- Write body of a loop to satisfy a given invariant.
  - Problem 6, Spring 2014 (Final)
- Given an invariant with code, identify all errors.
  - Problem 6, Spring 2014 (Prelim 2)
  - Problem 6, Spring 2013 (Final)
- Given an example, rewrite it with new invariant.
  - Problem 8, Fall 2014 (Final)
  - Problem 7, Fall 2018 (Final)

Exercise 6, Spring 2014 Final



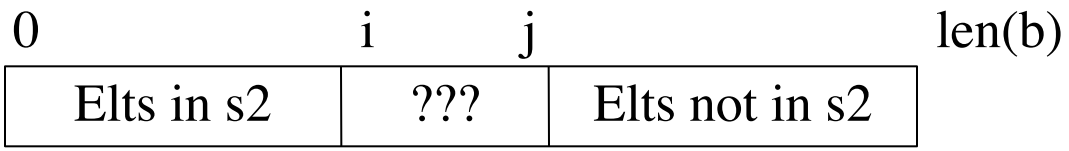
- **Example**:
- Input s1 = 'abracadabra', s2 = 'abc'
- Output 'abacaabardr' (or 'aaaabbcrdr')

Solution to Spring 2014 Final

```
# convert to a list b
b = list(s1)
# initialize counters


# inv: b[0..i-1] in s2; b[j+1..n-1] not in s2
while           :
    |
    |
    |
    |
    |
# post: b[0..j] in s2; b[i+1..n-1] not in s2
# convert b back to a string
```

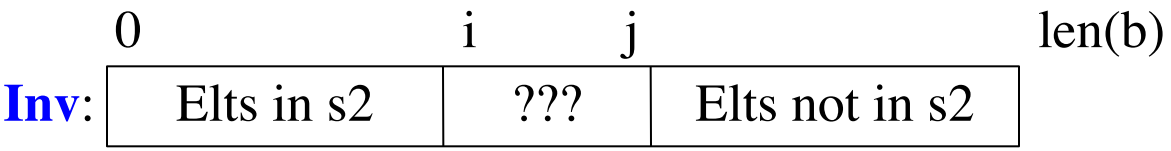
Solution to Spring 2014 Final

```
# convert to a list b
b = list(s1)
# initialize counters
i = 0
j = len(b) - 1
# inv: b[0..i-1] in s2; b[j+1..n-1] not in s2
while          :
    |
    |
    |
    |
    |
    |
# post: b[0..j] in s2; b[i+1..n-1] not in s2
# convert b back to a string
```



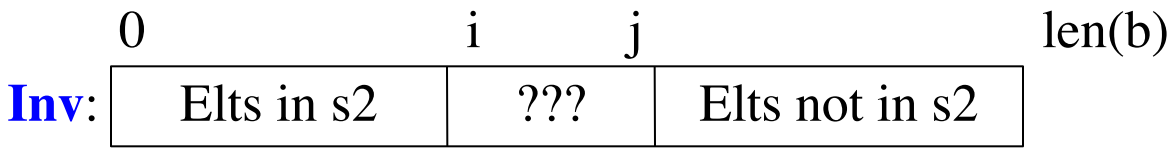
Solution to Spring 2014 Final

```
# convert to a list b
b = list(s1)
# initialize counters
i = 0
j = len(b) - 1
# inv: b[0..i-1] in s2; b[j+1..n-1] not in s2
while j != i - 1:
    |
    |
    |
    |
    |
# post: b[0..j] in s2; b[i+1..n-1] not in s2
# convert b back to a string
```



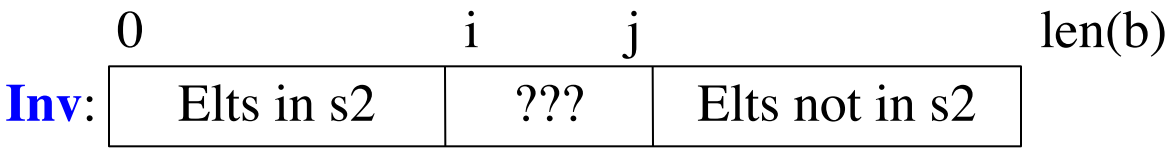
Solution to Spring 2014 Final

```
# convert to a list b
b = list(s1)
# initialize counters
i = 0
j = len(b) - 1
# inv: b[0..i-1] in s2; b[j+1..n-1] not in s2
while j != i - 1:
    if b[i] in s2:
        i = i + 1
    else:
        b[i], b[j] = b[j], b[i]    # Fancy swap syntax in python
        j = j - 1
# post: b[0..j] in s2; b[i+1..n-1] not in s2
# convert b back to a string
```



Solution to Spring 2014 Final

```
# convert to a list b
b = list(s1)
# initialize counters
i = 0
j = len(b) - 1
# inv: b[0..i-1] in s2; b[j+1..n-1] not in s2
while j != i - 1:
    if b[i] in s2:
        i = i + 1
    else:
        b[i], b[j] = b[j], b[i]   # Fancy swap syntax in python
        j = j - 1
# post: b[0..j] in s2; b[i+1..n-1] not in s2
# convert b back to a string
result = ''.join(b)
```

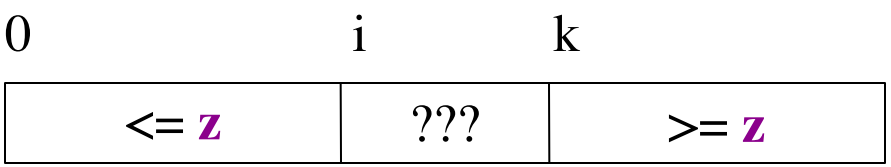


Three Types of Questions

- Write body of a loop to satisfy a given invariant.
  - Problem 6, Spring 2014 (Final)
- Given an invariant with code, identify all errors.
  - Problem 6, Spring 2014 (Prelim 2)
  - Problem 6, Spring 2013 (Final)
- Given an example, rewrite it with new invariant.
  - Problem 8, Fall 2014 (Final)
  - Problem 7, Fall 2018 (Final)

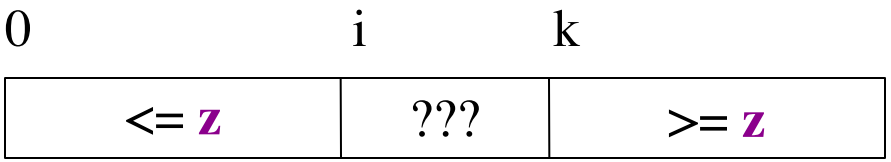
Exercise 6, Spring 2014 Prelim 2

```
def partition(b, z):
    i = 1
    k = len(b)
    # inv: b[0..i-1] <= z and b[k..] > z
    while i != k:
        if b[i] <= z:
            i = i + 1
        else:
            k = k-1
            b[i], b[k] = b[k], b[i]    # python swap
    # post: b[0..k-1] <= z and b[k..] > z
    return k
```



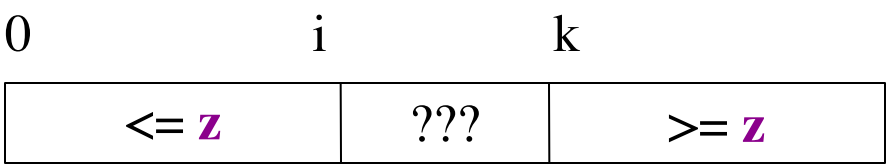
Exercise 6, Spring 2014 Prelim 2

```
def partition(b, z):
    i = 1      i = 0
    k = len(b)
    # inv: b[0..i-1] <= z and b[k..] > z
    while i != k:
        if b[i] <= z:
            i = i + 1
        else:
            k = k-1
            b[i], b[k] = b[k], b[i]    # python swap
    # post: b[0..k-1] <= z and b[k..] > z
    return k
```



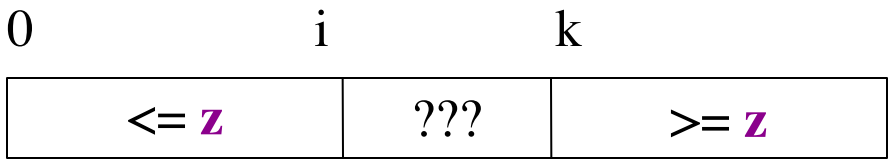
Exercise 6, Spring 2014 Prelim 2

```
def partition(b, z):
    i = -1
    k = len(b)
    # inv: b[0..i] <= z and b[k..] > z
    while i != k:
        if b[i+1] <= z:
            i = i + 1
        else:
            b[i+1], b[k-1] = b[k-1], b[i+1]    # python swap
            k = k-1
    # post: b[0..k-1] <= z and b[k..] > z
    return k
```



Exercise 6, Spring 2014 Prelim 2

```
def partition(b, z):
    i = -1
    k = len(b)
    # inv: b[0..i] <= z and b[k..] > z
    while i != k:   i != k-1:
        if b[i+1] <= z:
            i = i + 1
        else:
            b[i+1], b[k-1] = b[k-1], b[i+1]    # python swap
            k = k-1
    # post: b[0..k-1] <= z and b[k..] > z
    return k
```



Exercise 6, Spring 2013 Final

```
def num_space_runs(s):
    """The number of runs of spaces in the string s.
    Examples: ' a f g ' is 4 'a f g' is 2 ' a bc d' is 3.
    Precondition: len(s) >= 1"""
    i = 1
    n = 1 if s[0] == ' ' else 0
    # inv: s[0..i] contains n runs of spaces
    while i != len(s):
        if s[i] == ' ' and s[i-1] != ' ':
            n = n+1
        i = i+1
    # post: s[0..len(s)-1] contains n runs of spaces return n
    return n
```

Exercise 6, Spring 2013 Final

```
def num_space_runs(s):
    """The number of runs of spaces in the string s.
    Examples: ' a f g ' is 4 'a f g' is 2 ' a bc d' is 3.
    Precondition: len(s) >= 1"""
    i = 1    i = 0
    n = 1 if s[0] == ' ' else 0
    # inv: s[0..i] contains n runs of spaces
    while i != len(s):
        if s[i] == ' ' and s[i-1] != ' ':
            n = n+1
        i = i+1
    # post: s[0..len(s)-1] contains n runs of spaces return n
    return n
```

Exercise 6, Spring 2013 Final

```
def num_space_runs(s):
    """The number of runs of spaces in the string s.
    Examples: ' a f g ' is 4 'a f g' is 2 ' a bc d' is 3.
    Precondition: len(s) >= 1"""
    i = 1    i = 0
    n = 1 if s[0] == ' ' else 0
    # inv: s[0..i] contains n runs of spaces
    while i != len(s):  i != len(s)-1
        if s[i] == ' ' and s[i-1] != ' ':
            n = n+1
        i = i+1
    # post: s[0..len(s)-1] contains n runs of spaces return n
    return n
```

Exercise 6, Spring 2013 Final

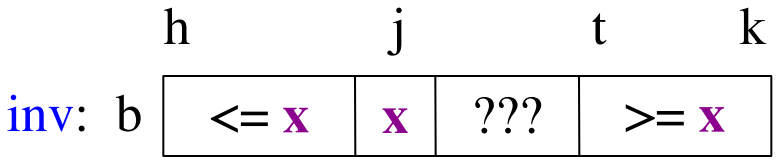
```
def num_space_runs(s):
    """The number of runs of spaces in the string s.
    Examples: ' a f g ' is 4 'a f g' is 2 ' a bc d' is 3.
    Precondition: len(s) >= 1"""
    i = 1    i = 0
    n = 1 if s[0] == ' ' else 0
    # inv: s[0..i] contains n runs of spaces
    while i != len(s):  i != len(s)-1
        if s[i] == ' ' and s[i-1] != ' ':   s[i+1] == ' ' and s[i] != ' ':
            n = n+1
        i = i+1
    # post: s[0..len(s)-1] contains n runs of spaces return n
    return n
```

Three Types of Questions

- Write body of a loop to satisfy a given invariant.
  - Problem 6, Spring 2014 (Final)
- Given an invariant with code, identify all errors.
  - Problem 6, Spring 2014 (Prelim 2)
  - Problem 6, Spring 2013 (Final)
- Given an example, rewrite it with new invariant.
  - Problem 8, Fall 2014 (Final)
  - Problem 7, Fall 2018 (Final)

Partition Example

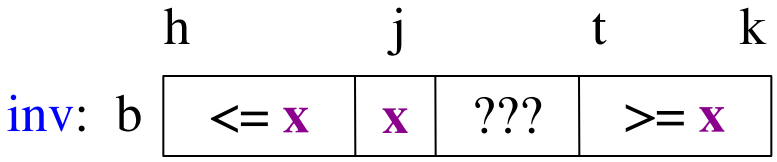
```
# Make invariant true at start
j = h
t = k+1
# inv: b[h..j-1] <= x = b[j] <= b[t..k]
while j < t-1:
    if b[j+1] <= b[j]:
        swap b[j] and b[j+1]
        j = j+1
    else:
        swap b[j+1] and b[t-1]
        t=t-1
# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```



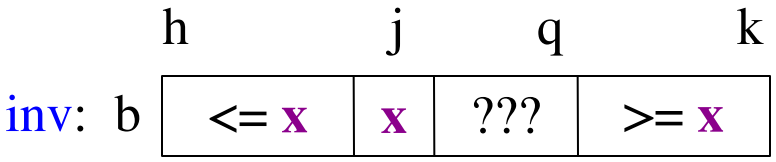

```
# Make invariant true at start
j =
q =
# inv: b[h..j-1] <= x = b[j] <= b[q+1..k]
while      :
    
    
    
    
    
    
# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```

Partition Example

```
# Make invariant true at start
j = h
t = k+1
# inv: b[h..j-1] <= x = b[j] <= b[t..k]
while j < t-1:
    if b[j+1] <= b[j]:
        swap b[j] and b[j+1]
        j = j+1
    else:
        swap b[j+1] and b[t-1]
        t=t-1
# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```

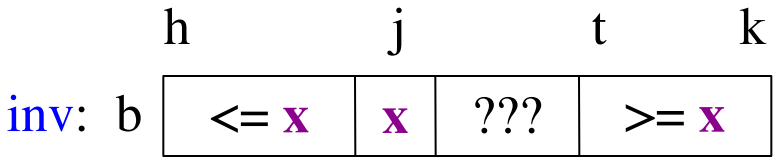



```
# Make invariant true at start
j =
q =
# inv: b[h..j-1] <= x = b[j] <= b[q+1..k]
while      :
    
    
    
    
    
    
    
    
# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```

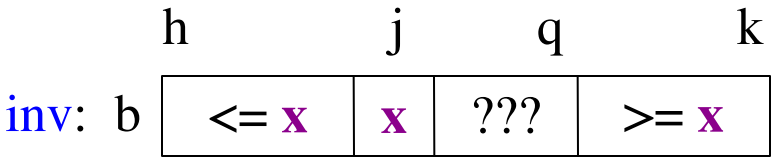


Partition Example

```
# Make invariant true at start
j = h
t = k+1
# inv: b[h..j-1] <= x = b[j] <= b[t..k]
while j < t-1:
    if b[j+1] <= b[j]:
        swap b[j] and b[j+1]
        j = j+1
    else:
        swap b[j+1] and b[t-1]
        t=t-1
# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```

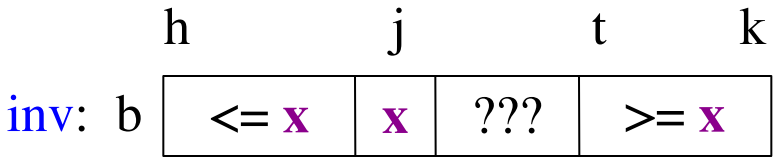



```
# Make invariant true at start
j = h
q = k
# inv: b[h..j-1] <= x = b[j] <= b[q+1..k]
while j < q:
    
    
    
    
    
    
    
    
# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```

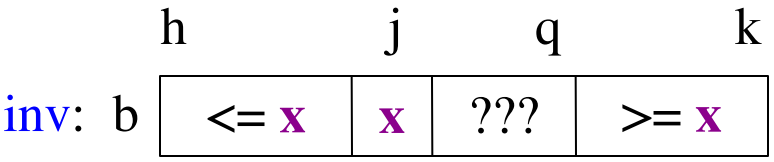


Partition Example

```
# Make invariant true at start
j = h
t = k+1
# inv: b[h..j-1] <= x = b[j] <= b[t..k]
while j < t-1:
    if b[j+1] <= b[j]:
        swap b[j] and b[j+1]
        j = j+1
    else:
        swap b[j+1] and b[t-1]
        t=t-1
# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```



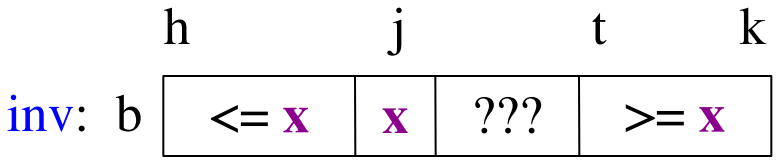

```
# Make invariant true at start
j = h
q = k
# inv: b[h..j-1] <= x = b[j] <= b[q+1..k]
while j < q:
    if b[j+1] <= b[j]:
        swap b[j] and b[j+1]
        j = j+1
    else:
        swap b[j+1] and b[q]
        q=q-1
# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```



Partition Example

```
# Make invariant true at start
j = h
t = k+1
# inv: b[h..j-1] <= x = b[j] <= b[t..k]
while j < t-1:
    if b[j+1] <= b[j]:
        swap b[j] and b[j+1]
        j = j+1
    else:
        swap b[j+1] and b[t-1]
        t=t-1
# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```

```
# Make invariant true at start
 j =
m =
# inv: b[h..j-1] <= x = b[j] <= b[j+1..m]
while      :
    |
    |
    |
    |
    |
    |
    |
    |
    |
# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```



Partition Example

```
# Make invariant true at start
j = h
t = k+1
# inv: b[h..j–1] <= x = b[j] <= b[t..k]
while j < t–1:
    if b[j+1] <= b[j]:
        swap b[j] and b[j+1]
        j = j+1
    else:
        swap b[j+1] and b[t-1]
        t=t–1
# post: b[h..j–1] <= x = b[j] <= b[j+1..k]
```

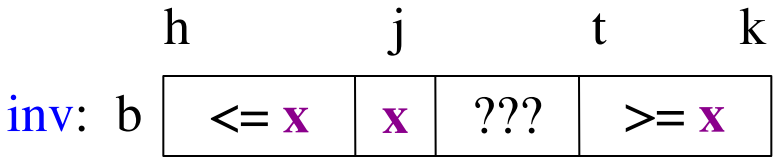
```
# Make invariant true at start
 j = h
m = h
# inv: b[h..j–1] <= x = b[j] <= b[j+1..m]
while      :

# post: b[h..j–1] <= x = b[j] <= b[j+1..k]
```

	h	j	t	k
inv: b	<= x	x	???	>= x

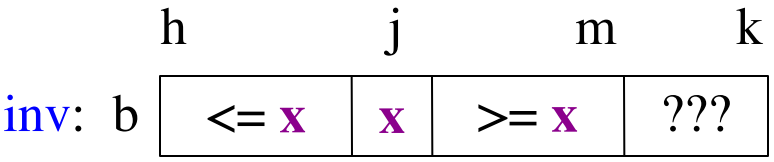
	h	j	m	k
inv: b	<= x	x	>= x	???

Partition Example

```
# Make invariant true at start
j = h
t = k+1
# inv: b[h..j-1] <= x = b[j] <= b[t..k]
while j < t-1:
    if b[j+1] <= b[j]:
        swap b[j] and b[j+1]
        j = j+1
    else:
        swap b[j+1] and b[t-1]
        t=t-1
# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```

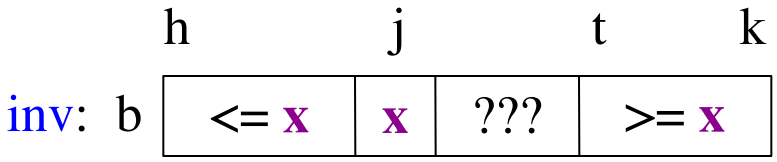



```
# Make invariant true at start
 j = h
m = h
# inv: b[h..j-1] <= x = b[j] <= b[j+1..m]
while m < k:

# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```

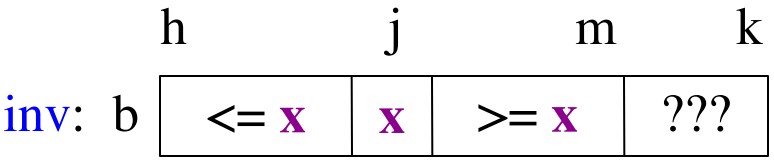


Partition Example

```
# Make invariant true at start
j = h
t = k+1
# inv: b[h..j-1] <= x = b[j] <= b[t..k]
while j < t-1:
    if b[j+1] <= b[j]:
        swap b[j] and b[j+1]
        j = j+1
    else:
        swap b[j+1] and b[t-1]
        t=t-1
# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```




```
# Make invariant true at start
 j = h
m = h
# inv: b[h..j-1] <= x = b[j] <= b[j+1..m]
while m < k:
    if b[m+1] <= b[j]:
        swap b[j] and b[m+1]
        swap b[j+1] and b[m+1]
        m = m+1; j=j+1
    else:
        m = m+1
# post: b[h..j-1] <= x = b[j] <= b[j+1..k]
```



What is Fair Game for this Question?

- Segregation (see Fall 2014 Final)
- Partition from **Lab 13**
- Dutch-National-Flag from **Lab 13**
- The non-recursive sorting algorithms
  - Insertion Sort (**Lecture 27**)
  - Selection Sort (**Lecture 27**)
  - But changing invariants changes helpers too
- Binary Search (**Lectures 26 & 27**)

Questions?