- Previous Lecture:
  - Acoustic data: frequency computation
  - Touchtone phone
- Today's Lecture:
  - Search: Linear Search
  - Sort: Bubble Sort and Insertion Sort
  - Efficiency Analysis
- Announcements:
  - Prelim 3 scores will be posted on Sunday; paper will be returned next Tues

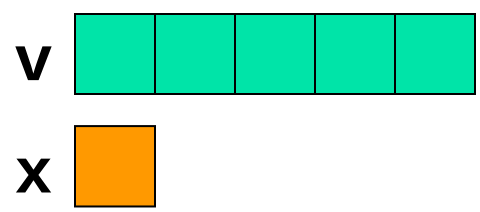
Searching for an item in a collection

Is the collection organized?
What is the organizing scheme?

Indiana Jones and the Raiders of the Lost Ark

Searching for an item in an unorganized collection?

- May need to look through the whole collection to find the target item
- E.g., find value x in vector v



- Linear search

```
% f is index of first occurrence
%   of value x in vector v.
% f is -1 if x not found.
k= 1;
while  k<=length(v) && v(k)~=x
    k= k + 1;
end
if  k>length(v)
    f= -1; % signal for x not found
else
    f= k;
end
```

```
% Linear Search
% f is index of first occurrence
%   of value x in vector v.
% f is -1 if x not found.
k= 1;
while  k<=length(v) && v(k)~=x
    k= k + 1;
end
if  k>length(v)
    f= -1; % signal for x not found
else
    f= k;
end
```

v	12	35	33	15	42	45
x	31					

```
% Linear Search
% f is index of first occurrence
%   of value x in vector v.
% f is -1 if x not found.
k= 1;
while  k<=length(v) && v(k)~=x
    k= k + 1;
end
if  k>length(v)
    f= -1; % signal for x not found
else
    f= k;
end
```

A. squared

B. doubled

C. the same

D. halved

Suppose another vector is twice as long as v. The expected “effort” required to do a linear search is …

```
% Linear Search
% f is index of first occurrence
%   of value x in vector v.
% f is -1 if x not found.
k= 1;
while  k<=length(v) && v(k)~=x
    k= k + 1;
end
if  k>length(v)
    f= -1; % signal for x not found
else
    f= k;
end
```

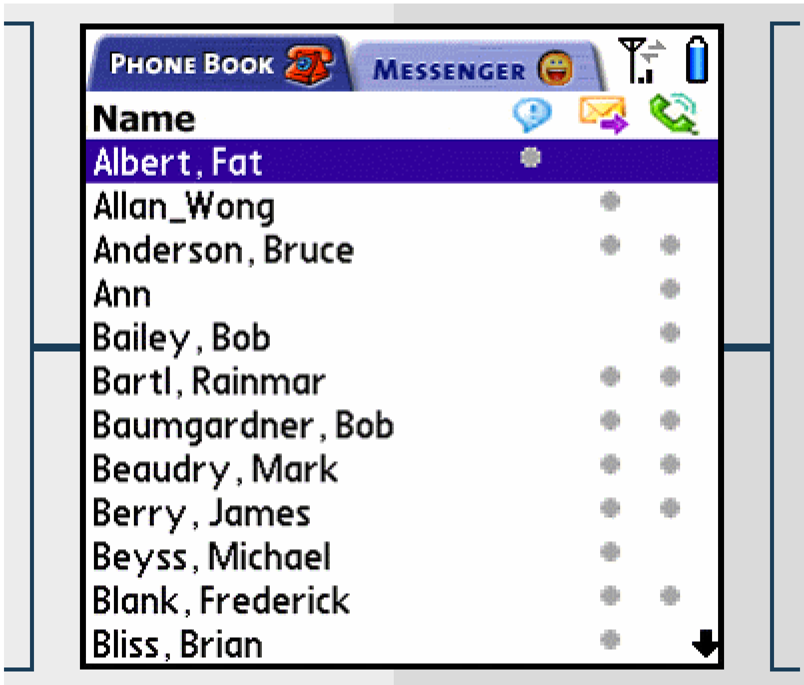
v	12	35	33	15	42	45
x	31					

```
% Linear Search
% f is index of first occurrence
%   of value x in vector v.
% f is -1 if x not found.
k= 1;
while  k<=length(v) && v(k)~=x
    k= k + 1;
end
if  k>length(v)
    f= -1; % signal for x not found
else
    f= k;
end
```

v	12	15	33	35	42	45
x	31					

What if **v** is sorted?

Sorting data allows us to search more easily

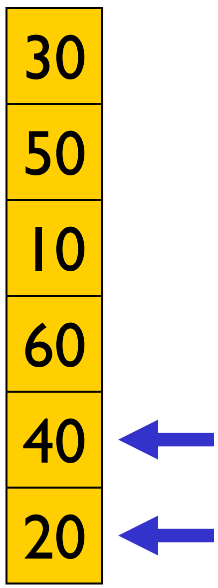


Boston Marathon Top Women Finishers

			Official Time	State	Country	Ctz
			2:25:25		ETH	
			2:25:27		RUS	
			2:26:34		KEN	
			2:28:12		LAT	
			2:29:48		ETH	
			2:30:52		ITA	
7	F12	Olaru, Nuta	2:33:56		ROM	
8	F6	Guta, Robe Tola	2:34:37		ETH	
9	F1	Grigoryeva, Lidiya	2:35:37		RUS	
	F35	Hood, Stephanie A.	2:44:44	IL	USA	CAN
	F14	Robson, Denise C.	2:45:54	NS	CAN	
	F11	Chemjor, Magdaline	2:46:25		KEN	
	F101	Sultanova-Zhdanova, Firaya	2:47:17	FL	USA	RUS
	F15	Mayger, Eliza M.	2:47:36		AUS	
	F24	Anklam, Ashley A.	2:48:43	MN	USA	

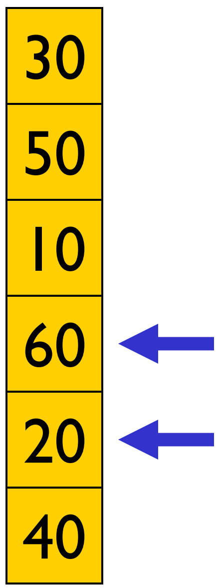
Name	Score	Grade
Jorge	92.1	
Ahn	91.5	
Oluban	90.6	
Chi	88.9	
Minale	88.1	
Roll	87.3	

The “bubble” process



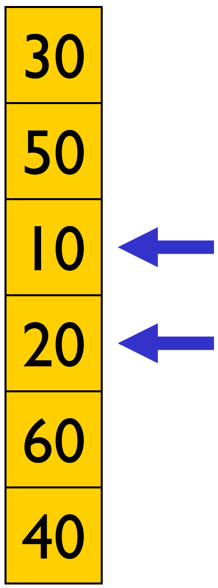
Compare adjacent values.
Swap if “out of order.”

The “bubble” process



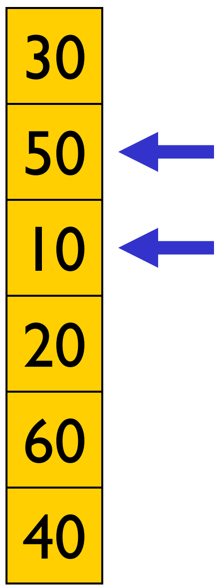
Compare adjacent values.
Swap if “out of order.”

The “bubble” process



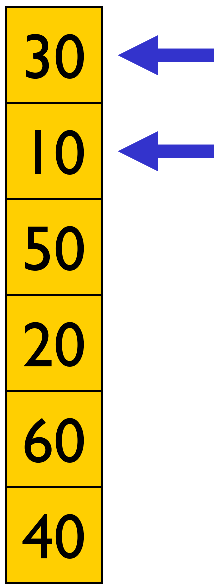
Compare adjacent values.
Swap if “out of order.”

The “bubble” process



Compare adjacent values.
Swap if “out of order.”

The “bubble” process



Compare adjacent values.
Swap if “out of order.”

The "bubble" process

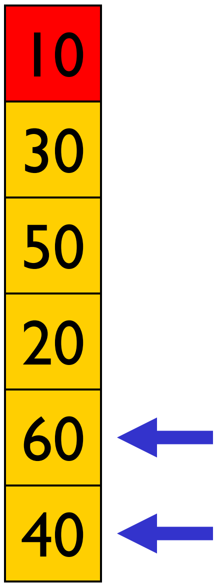
10
30
50
20
60
40

The smallest (lightest) value "bubbles" to the top

Done in one pass through the vector

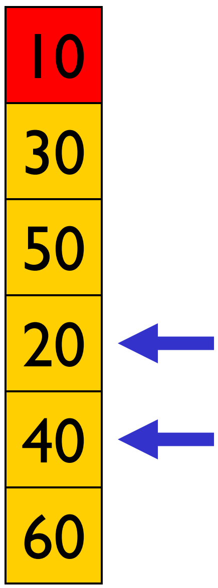
`Bubble.m`

The second “bubble” process



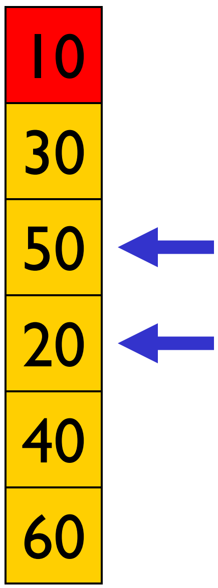
Compare adjacent values.
Swap if “out of order.”

The second “bubble” process



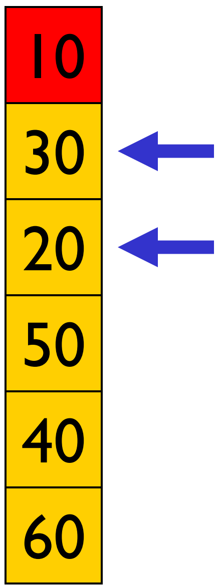
Compare adjacent values.
Swap if “out of order.”

The second "bubble" process



Compare adjacent values.
Swap if "out of order."

The second “bubble” process



Compare adjacent values.
Swap if “out of order.”

The second “bubble” process

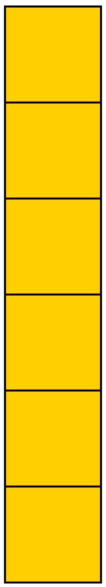
10
20
30
50
40
60

After two bubble processes, the first two components are sorted.

Repeatedly apply the bubble process to sort the whole array

Sort vector **x** using the Bubble Sort algorithm

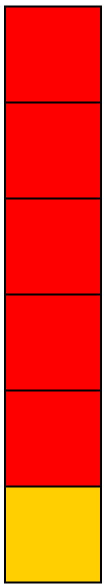
x



Apply **Bubble** to **x**: **[x,C,S] = Bubble(x)**

Sort vector **x** using the Bubble Sort algorithm

x



Bubble `x`: `[x,C,S] = Bubble(x)`

Bubble `x(2:6)`: `[x(2:6),C,S] = Bubble(x(2:6))`

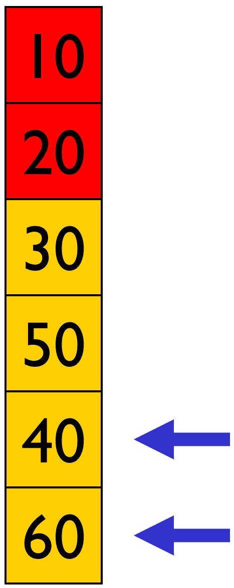
Bubble `x(3:6)`: `[x(3:6),C,S] = Bubble(x(3:6))`

Bubble `x(4:6)`: `[x(4:6),C,S] = Bubble(x(4:6))`

Bubble `x(5:6)`: `[x(5:6),C,S] = Bubble(x(5:6))`

`BubbleSort1.m`

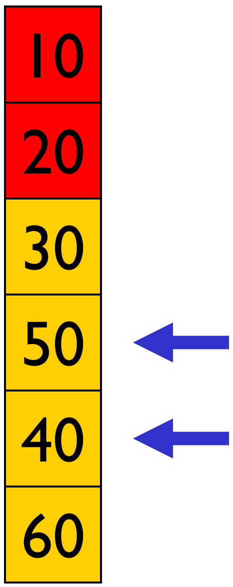
Possible to get a sorted vector before n-1 "bubble" processes



After 2 bubble processes…

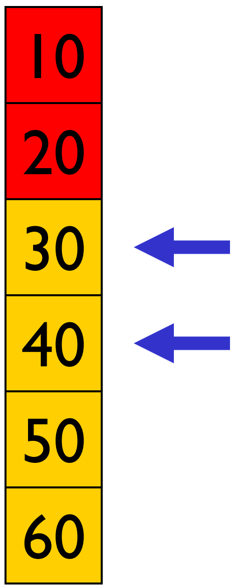
Start 3rd bubble process

Possible to get a sorted vector before n-1 “bubble” processes



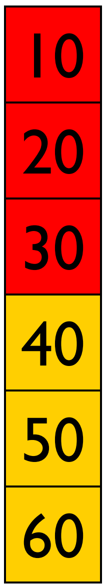
In the 3rd bubble process

Possible to get a sorted vector before *n*-1 "bubble" processes



In the 3rd bubble process

Possible to get a sorted vector before n-1 "bubble" processes



After the 3rd bubble process

Vector is completely sorted (in this example)

How to improve **`BubbleSort`** to quit early?

Possible to get a sorted vector before *n*-1 "bubble" processes

10
20
30
40
50
60

After the 3rd bubble process

Vector is completely sorted (in this example)

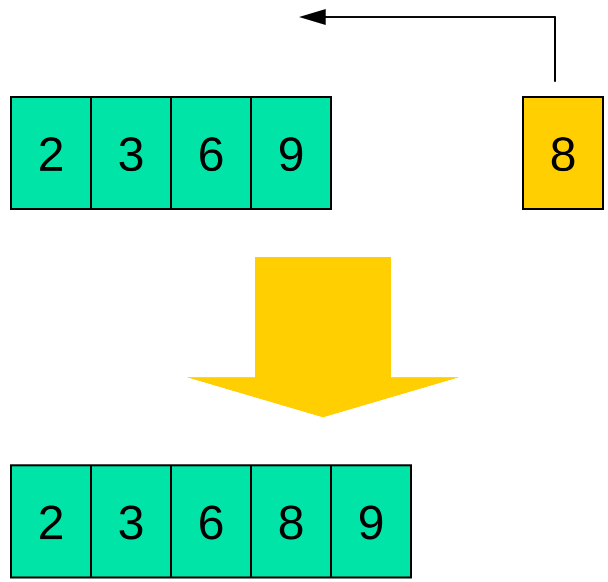
How to improve **`BubbleSort`** to quit early?

Keep track of the swaps! No swap is done when vector is sorted.

`BubbleSort.m`

The Insertion Process

- Given a sorted array x, insert a number y such that the result is sorted



Insertion

2	3	6	9	8

2	3	6	8	9

Just swap 8 & 9

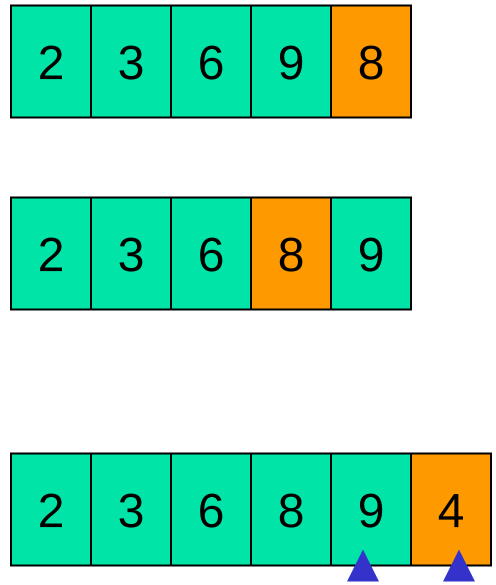
Insertion

2	3	6	9	8

2	3	6	8	9

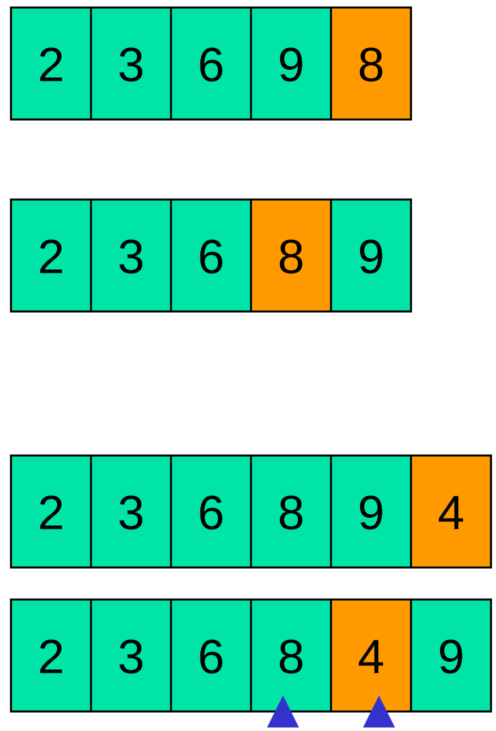
2	3	6	8	9

Insertion



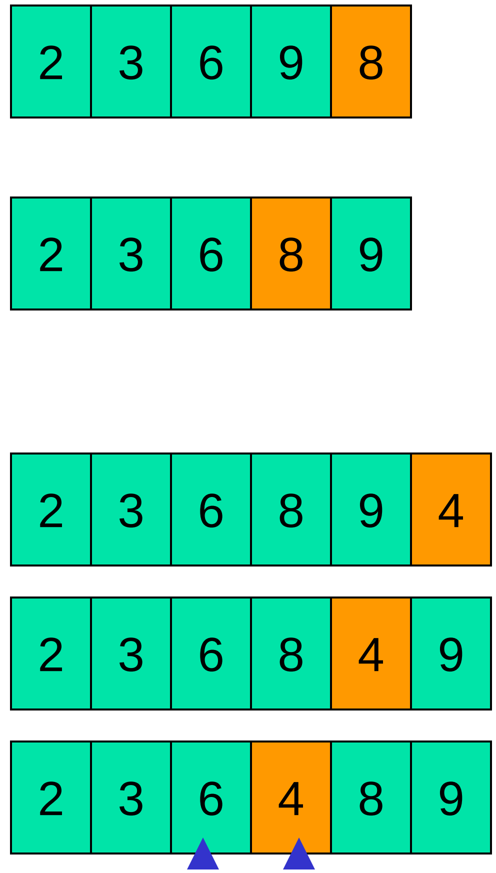
Compare adjacent components:
swap 9 & 4

Insertion



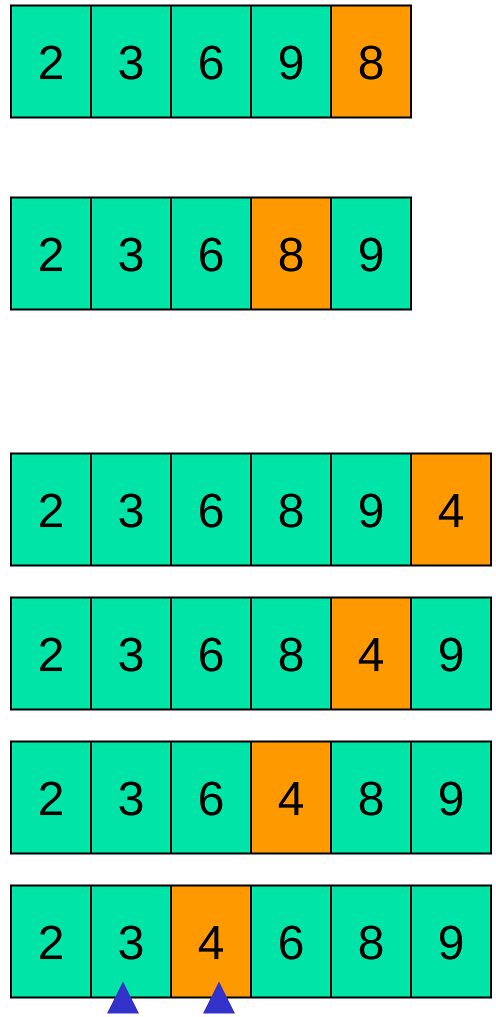
Compare adjacent components:
swap 8 & 4

Insertion



Compare adjacent components:
swap 6 & 4

Insertion



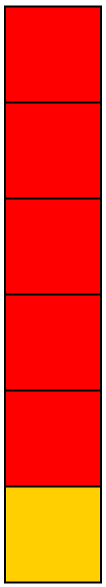
Compare adjacent components:
DONE! No more swaps.

`Insert.m`

Sort vector **x** using the Insertion Sort algorithm

Need to start with a *sorted* subvector. How do you find one?

x



Length 1 subvector is "sorted"

Insert `x(2)`: `[x(1:2),C,S] = Insert(x(1:2))`

Insert `x(3)`: `[x(1:3),C,S] = Insert(x(1:3))`

Insert `x(4)`: `[x(1:4),C,S] = Insert(x(1:4))`

Insert `x(5)`: `[x(1:5),C,S] = Insert(x(1:5))`

Insert `x(6)`: `[x(1:6),C,S] = Insert(x(1:6))`

`InsertionSort.m`

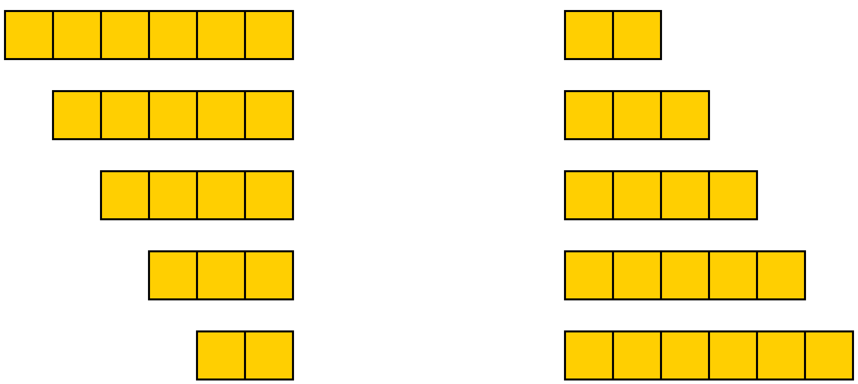
Bubble Sort vs. Insertion Sort

- Both involve comparing adjacent values and swaps
- On average, which is more efficient?

A. Bubble Sort

B. Insertion Sort

C. They're the same



Other efficiency considerations

- Worst case, best case, average case
- Use of subfunction incurs an “overhead”
- Memory use and access

- Example: Rather than directing the *insert* process to a subfunction, have it done “in-line.”
- Also, Insertion sort can be done “in-place,” i.e., using “only” the memory space of the original vector.

```
function x = insertSort(x)
% Sort vector x in ascending order with insertion sort

n = length(x);
for i= 1:n-1
      % Sort x(1:i+1) given that x(1:i) is sorted









end
```

```
function x = insertSort(x)
% Sort vector x in ascending order with insertion sort

n = length(x);
for i= 1:n-1
      % Sort x(1:i+1) given that x(1:i) is sorted
      j= i;
      need2swap=
      while  need2swap

          % swap x(j+1) and x(j)




          j= j-1;
          need2swap=
      end
end
```

```
function x = insertSort(x)
% Sort vector x in ascending order with insertion sort

n = length(x);
for i= 1:n-1
      % Sort x(1:i+1) given that x(1:i) is sorted
      j= i;
      need2swap= x(j+1) < x(j);
      while  need2swap

          % swap x(j+1) and x(j)





          j= j-1;
          need2swap= j>0 && x(j+1)<x(j);
      end
end
```

```
function x = insertSort(x)
% Sort vector x in ascending order with insertion sort

n = length(x);
for i= 1:n-1
      % Sort x(1:i+1) given that x(1:i) is sorted
      j= i;
      need2swap= x(j+1) < x(j);
      while  need2swap

          % swap x(j+1) and x(j)
            temp= x(j);
            x(j)= x(j+1);
            x(j+1)= temp;

          j= j-1;
          need2swap= j>0 && x(j+1)<x(j);
      end
end
```