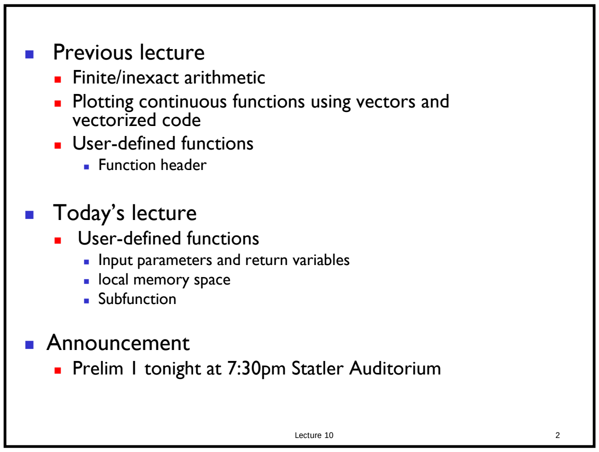
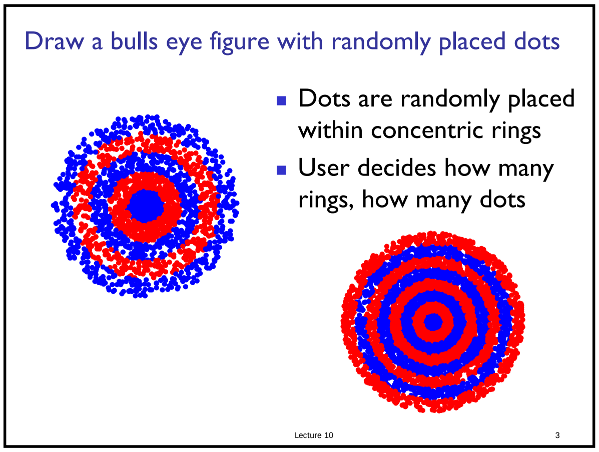
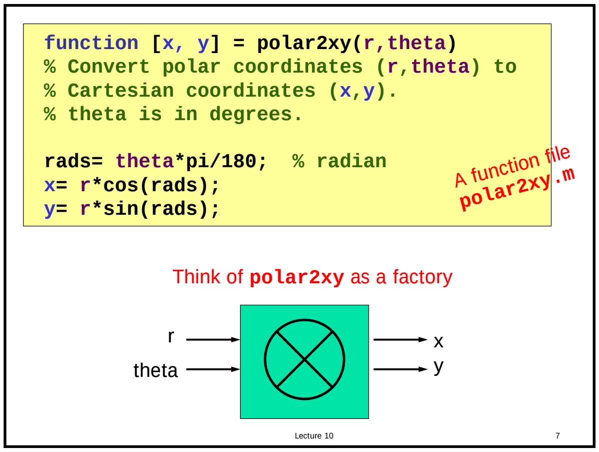


- Previous lecture
  - Finite/inexact arithmetic
  - Plotting continuous functions using vectors and vectorized code
  - User-defined functions
    - Function header
- Today's lecture
  - User-defined functions
    - Input parameters and return variables
    - local memory space
    - Subfunction
- Announcement
  - Prelim 1 tonight at 7:30pm Statler Auditorium



## Draw a bulls eye figure with randomly placed dots

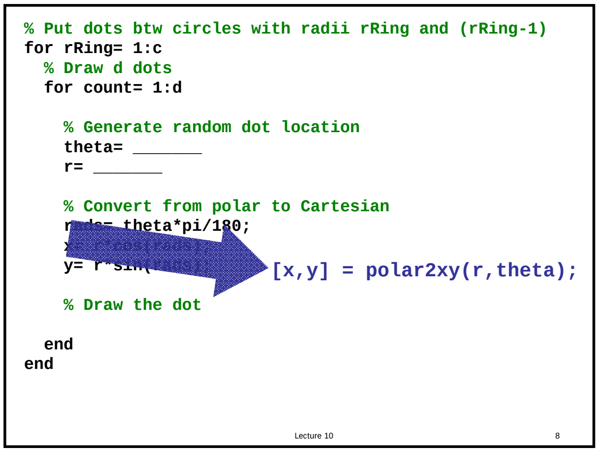
- Dots are randomly placed within concentric rings
- User decides how many rings, how many dots



```
function [x, y] = polar2xy(r,theta)
% Convert polar coordinates (r,theta) to
% Cartesian coordinates (x,y).
% theta is in degrees.

rads= theta*pi/180;  % radian
x= r*cos(rads);
y= r*sin(rads);
```

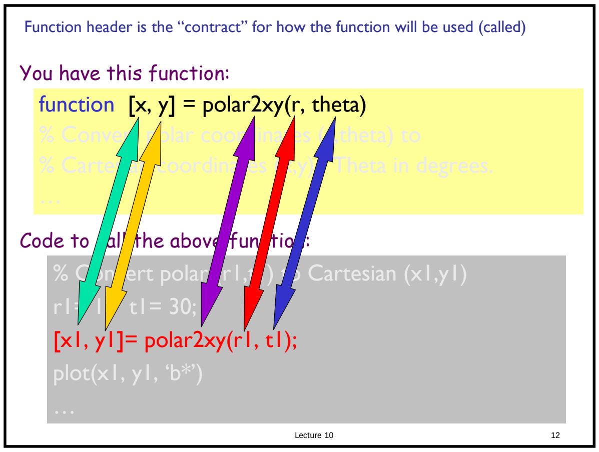
A function file **polar2xy.m**

Think of **polar2xy** as a factory



```
% Put dots btw circles with radii rRing and (rRing-1)
for rRing= 1:c
  % Draw d dots
  for count= 1:d

    % Generate random dot location
    theta= _______
    r= _______

    % Convert from polar to Cartesian
    rads= theta*pi/180;
    x= r*cos(rads);
    y= r*sin(rads);

    % Draw the dot

  end
end
```

```
[x,y] = polar2xy(r,theta);
```



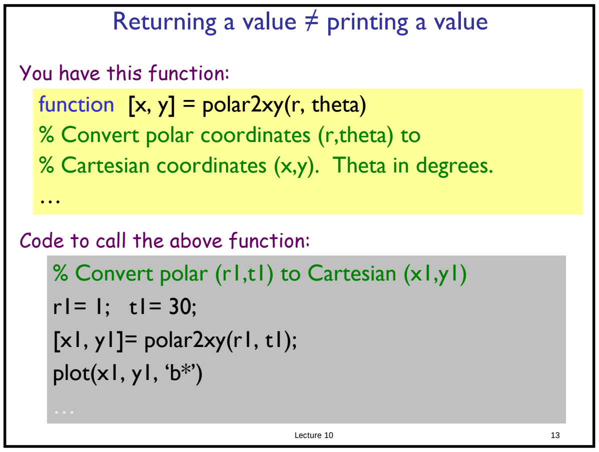
Function header is the "contract" for how the function will be used (called)

You have this function:

```
function  [x, y] = polar2xy(r, theta)
% Convert polar coordinates (r,theta) to
% Cartesian coordinates (x,y).  Theta in degrees.
…
```

Code to call the above function:

```
% Convert polar (r1,t1) to Cartesian (x1,y1)
r1= 1;   t1= 30;
[x1, y1]= polar2xy(r1, t1);
plot(x1, y1, 'b*')
…
```



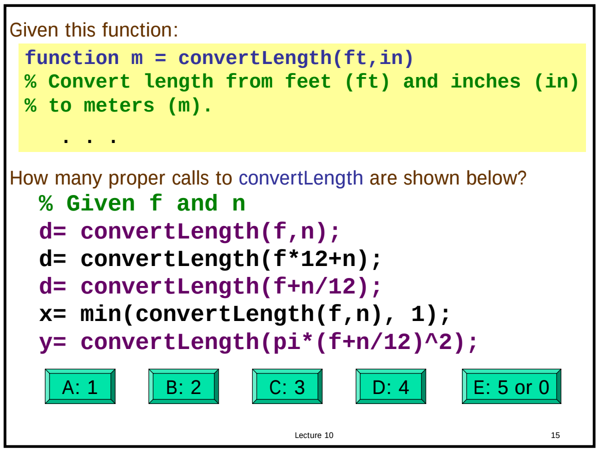
## Returning a value ≠ printing a value

You have this function:

```
function  [x, y] = polar2xy(r, theta)
% Convert polar coordinates (r,theta) to
% Cartesian coordinates (x,y).  Theta in degrees.
…
```

Code to call the above function:

```
% Convert polar (r1,t1) to Cartesian (x1,y1)
r1= 1;   t1= 30;
[x1, y1]= polar2xy(r1, t1);
plot(x1, y1, 'b*')
…
```



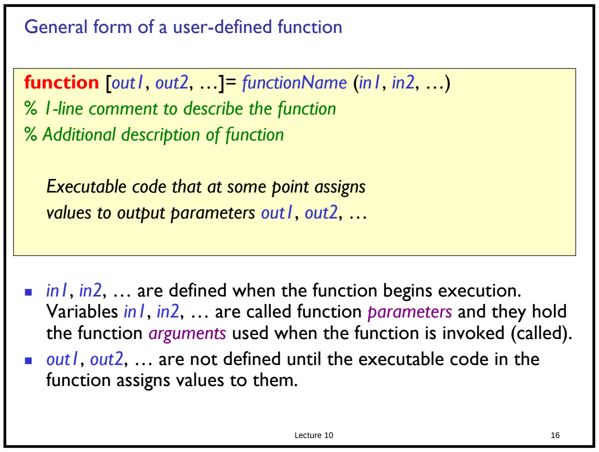
Given this function:

```
function m = convertLength(ft,in)
% Convert length from feet (ft) and inches (in)
% to meters (m).
   . . .
```

How many proper calls to convertLength are shown below?

```
% Given f and n
d= convertLength(f,n);
d= convertLength(f*12+n);
d= convertLength(f+n/12);
x= min(convertLength(f,n), 1);
y= convertLength(pi*(f+n/12)^2);
```

A: 1 | B: 2 | C: 3 | D: 4 | E: 5 or 0

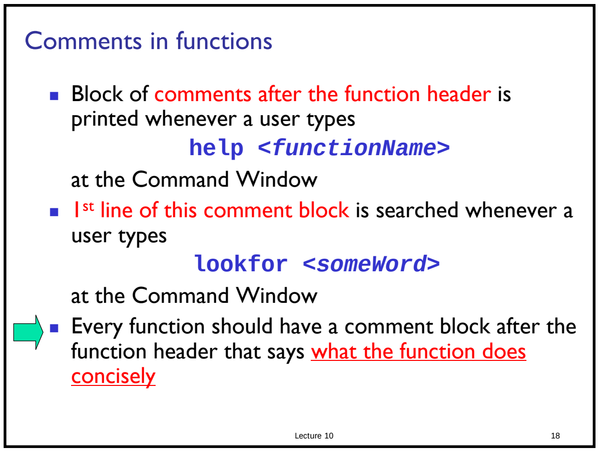


General form of a user-defined function

**function** [*out1*, *out2*, …]= *functionName* (*in1*, *in2*, …)
*% 1-line comment to describe the function*
*% Additional description of function*

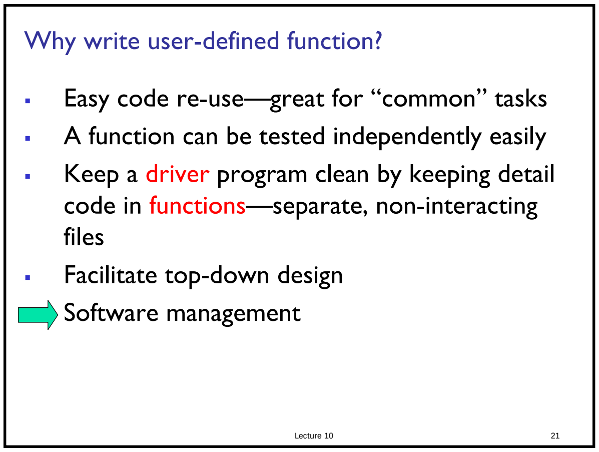
*Executable code that at some point assigns values to output parameters out1, out2, …*

- *in1*, *in2*, … are defined when the function begins execution. Variables *in1*, *in2*, … are called function *parameters* and they hold the function *arguments* used when the function is invoked (called).
- *out1*, *out2*, … are not defined until the executable code in the function assigns values to them.



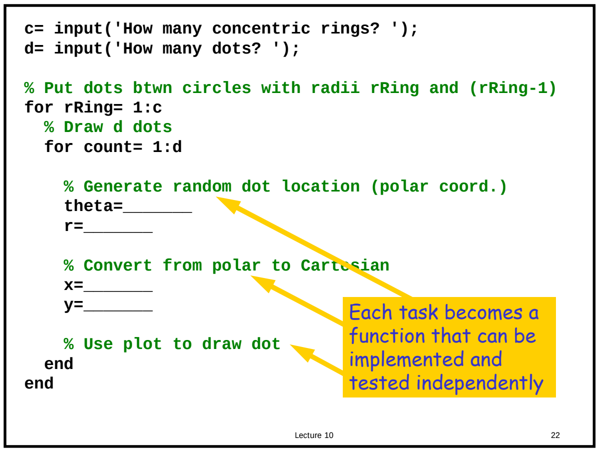
Comments in functions

- Block of comments after the function header is printed whenever a user types
  **help *<functionName>***
  at the Command Window
- 1st line of this comment block is searched whenever a user types
  **lookfor *<someWord>***
  at the Command Window
- Every function should have a comment block after the function header that says what the function does concisely



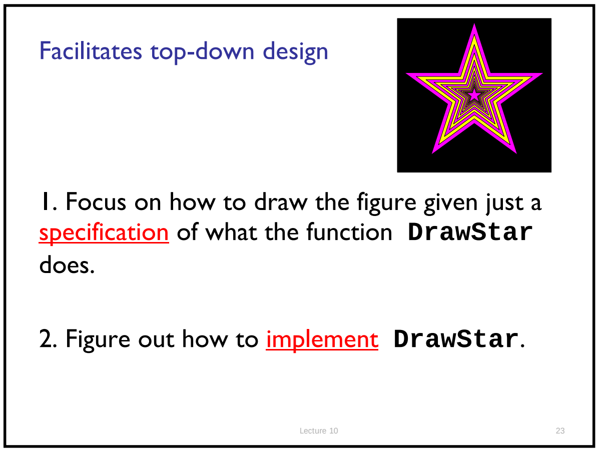
Why write user-defined function?

- Easy code re-use—great for “common” tasks
- A function can be tested independently easily
- Keep a driver program clean by keeping detail code in functions—separate, non-interacting files
- Facilitate top-down design
- Software management



```
c= input('How many concentric rings? ');
d= input('How many dots? ');

% Put dots btwn circles with radii rRing and (rRing-1)
for rRing= 1:c
  % Draw d dots
  for count= 1:d

    % Generate random dot location (polar coord.)
    theta=_______
    r=_______

    % Convert from polar to Cartesian
    x=_______
    y=_______

    % Use plot to draw dot
  end
end
```

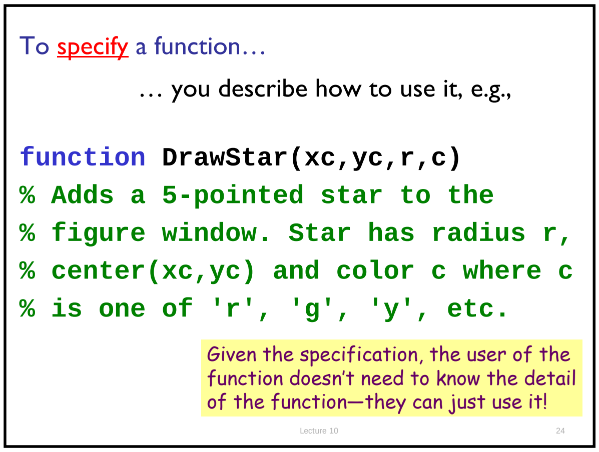
Each task becomes a function that can be implemented and tested independently



Facilitates top-down design

1. Focus on how to draw the figure given just a specification of what the function **DrawStar** does.

2. Figure out how to implement **DrawStar**.

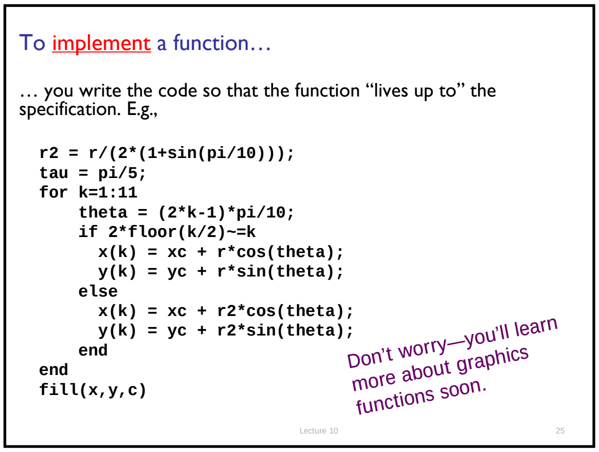


## To specify a function…

… you describe how to use it, e.g.,

```
function DrawStar(xc,yc,r,c)
% Adds a 5-pointed star to the
% figure window. Star has radius r,
% center(xc,yc) and color c where c
% is one of 'r', 'g', 'y', etc.
```

Given the specification, the user of the function doesn't need to know the detail of the function—they can just use it!

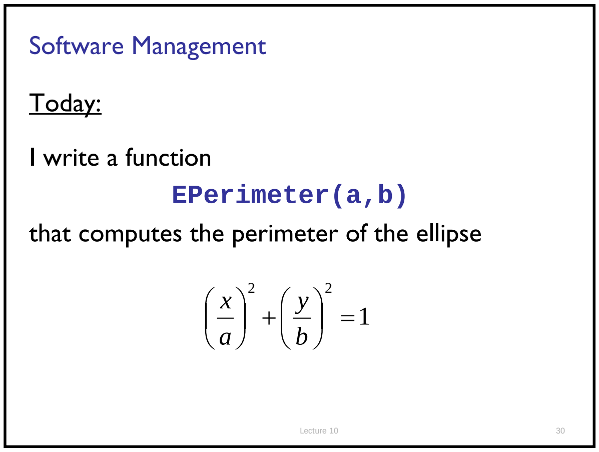


## To implement a function…

… you write the code so that the function "lives up to" the specification. E.g.,

```
r2 = r/(2*(1+sin(pi/10)));
tau = pi/5;
for k=1:11
    theta = (2*k-1)*pi/10;
    if 2*floor(k/2)~=k
      x(k) = xc + r*cos(theta);
      y(k) = yc + r*sin(theta);
    else
      x(k) = xc + r2*cos(theta);
      y(k) = yc + r2*sin(theta);
    end
end
fill(x,y,c)
```

Don't worry—you'll learn more about graphics functions soon.



## Software Management

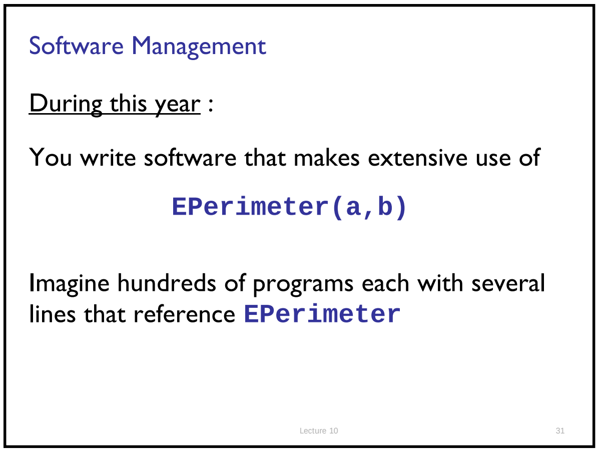
Today:

I write a function

**EPerimeter(a,b)**

that computes the perimeter of the ellipse

$$\left(\frac{x}{a}\right)^2+\left(\frac{y}{b}\right)^2=1$$



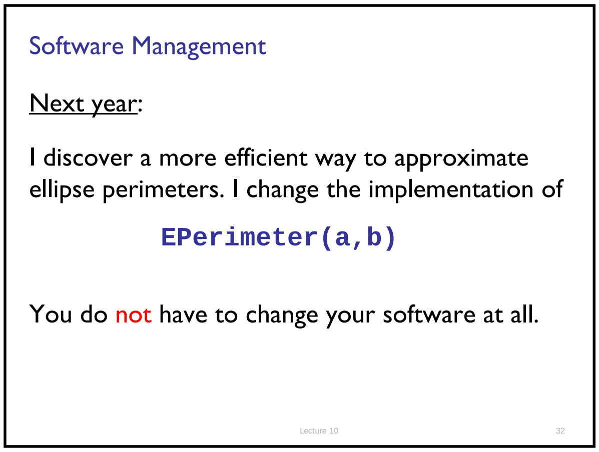
## Software Management

During this year :

You write software that makes extensive use of

**EPerimeter(a,b)**

Imagine hundreds of programs each with several lines that reference **EPerimeter**



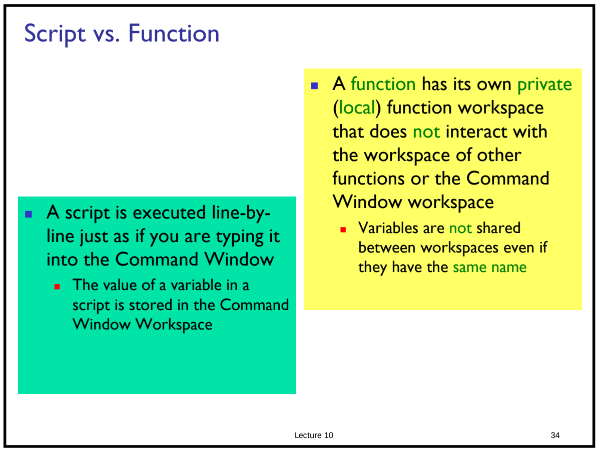
## Software Management

Next year:

I discover a more efficient way to approximate ellipse perimeters. I change the implementation of

**EPerimeter(a,b)**

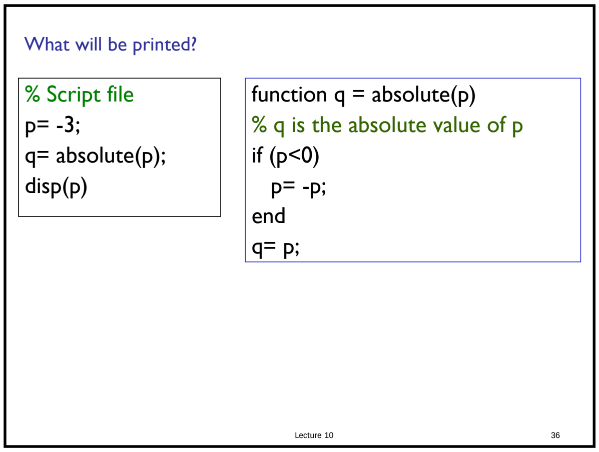
You do not have to change your software at all.



## Script vs. Function

- A script is executed line-by-line just as if you are typing it into the Command Window
  - The value of a variable in a script is stored in the Command Window Workspace

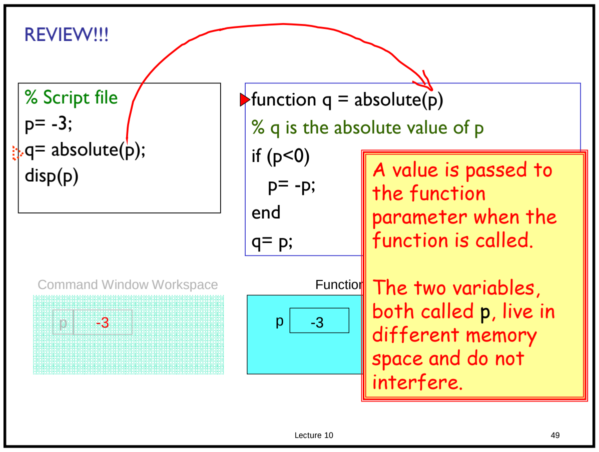
- A function has its own private (local) function workspace that does not interact with the workspace of other functions or the Command Window workspace
  - Variables are not shared between workspaces even if they have the same name



What will be printed?

```
% Script file
p= -3;
q= absolute(p);
disp(p)
```

```
function q = absolute(p)
% q is the absolute value of p
if (p<0)
   p= -p;
end
q= p;
```



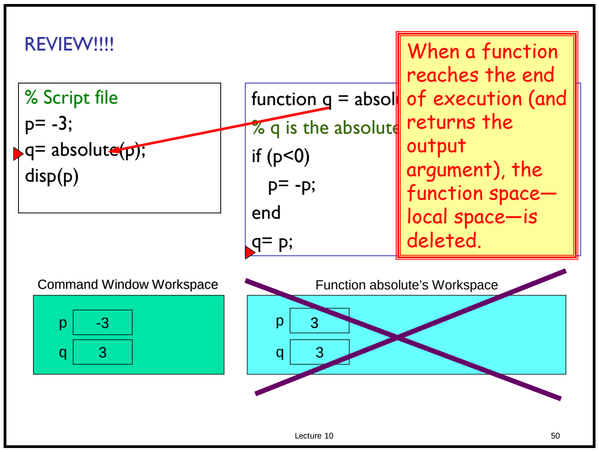
REVIEW!!!

```
% Script file
p= -3;
q= absolute(p);
disp(p)
```

```
function q = absolute(p)
% q is the absolute value of p
if (p<0)
   p= -p;
end
q= p;
```

A value is passed to the function parameter when the function is called.

The two variables, both called p, live in different memory space and do not interfere.

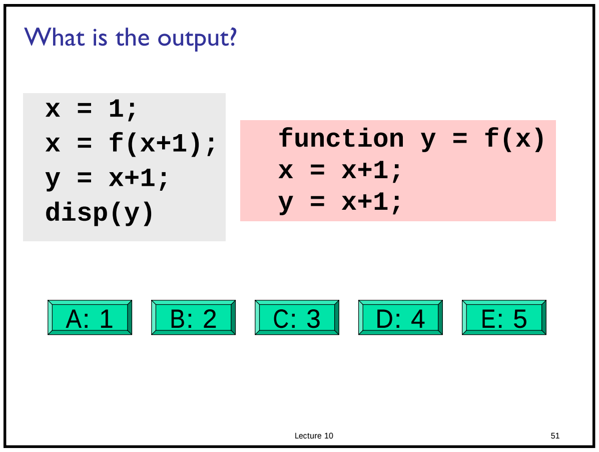


REVIEW!!!!

```
% Script file
p= -3;
q= absolute(p);
disp(p)
```

```
function q = absol
% q is the absolute
if (p<0)
   p= -p;
end
q= p;
```

When a function reaches the end of execution (and returns the output argument), the function space—local space—is deleted.

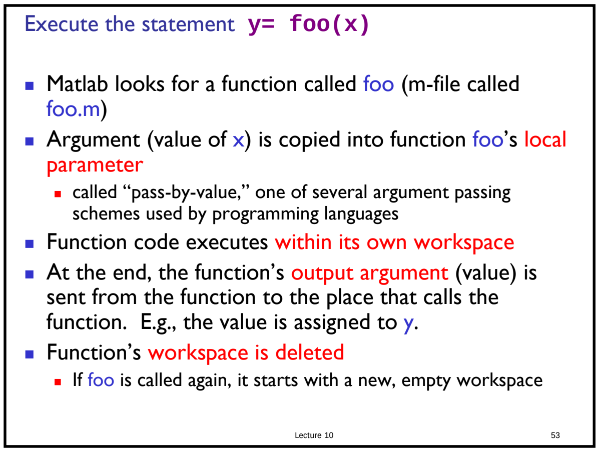


What is the output?

```
x = 1;
x = f(x+1);
y = x+1;
disp(y)
```

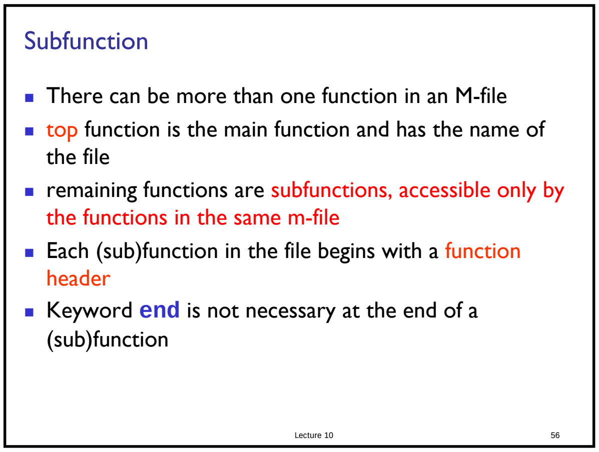
```
function y = f(x)
x = x+1;
y = x+1;
```

A: 1 B: 2 C: 3 D: 4 E: 5



Execute the statement **y= foo(x)**

- Matlab looks for a function called foo (m-file called foo.m)
- Argument (value of x) is copied into function foo's local parameter
  - called "pass-by-value," one of several argument passing schemes used by programming languages
- Function code executes within its own workspace
- At the end, the function's output argument (value) is sent from the function to the place that calls the function. E.g., the value is assigned to y.
- Function's workspace is deleted
  - If foo is called again, it starts with a new, empty workspace



Subfunction

- There can be more than one function in an M-file
- top function is the main function and has the name of the file
- remaining functions are subfunctions, accessible only by the functions in the same m-file
- Each (sub)function in the file begins with a function header
- Keyword **end** is not necessary at the end of a (sub)function