- **Previous lecture**
    - **User-defined functions**
        - Function header
        - Input parameters and return variables

- **Today's lecture**
    - **User-defined functions**
        - local memory space
        - Subfunction
    - **1-dimensional array and plot**

- **Announcement**
    - Discussion this week in classrooms as listed in Student Center
    - Make use of consulting/office hours

Draw a bulls eye figure with randomly placed dots
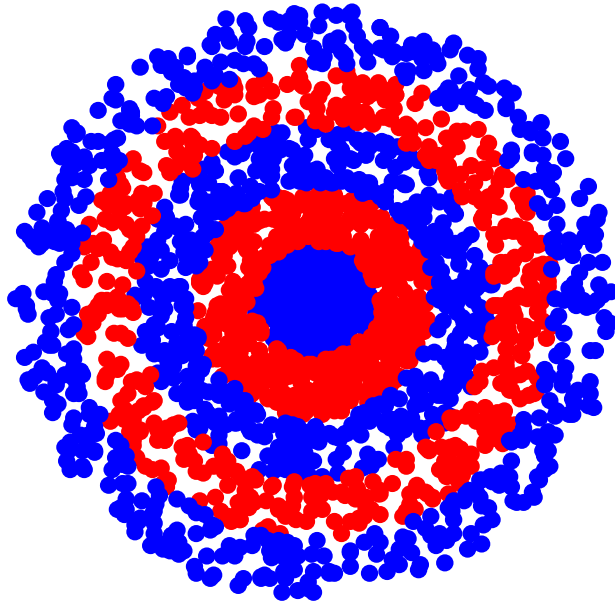
- **Dots are randomly placed within concentric rings**
- **User decides how many rings, how many dots**
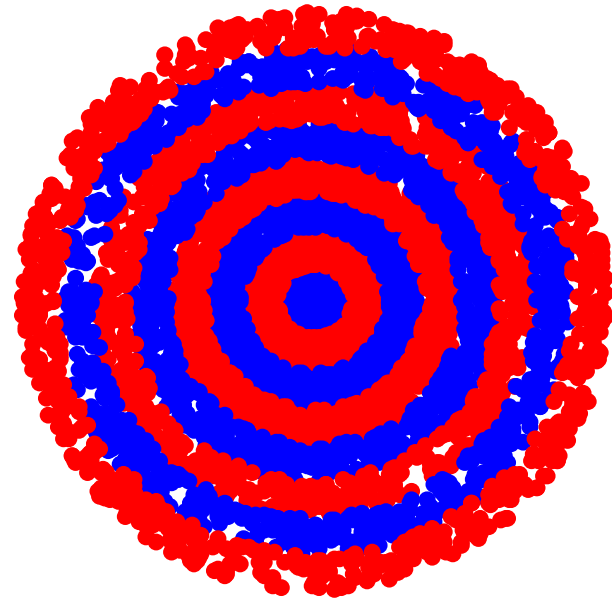
General form of a user-defined function

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.

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.
...   fprintf ('(%.1f , %.1f)\n', x , y)

Function prints instead of returns values

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*')
...

Not possible to do

Now, although you can see the coordinates, this script cannot use them.

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 |

Comments in functions

- Block of comments after the function header is printed whenever a user types

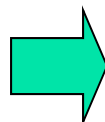 **help <functionName>**

  at the Command Window

- 1st line of this comment block is searched whenever a user types

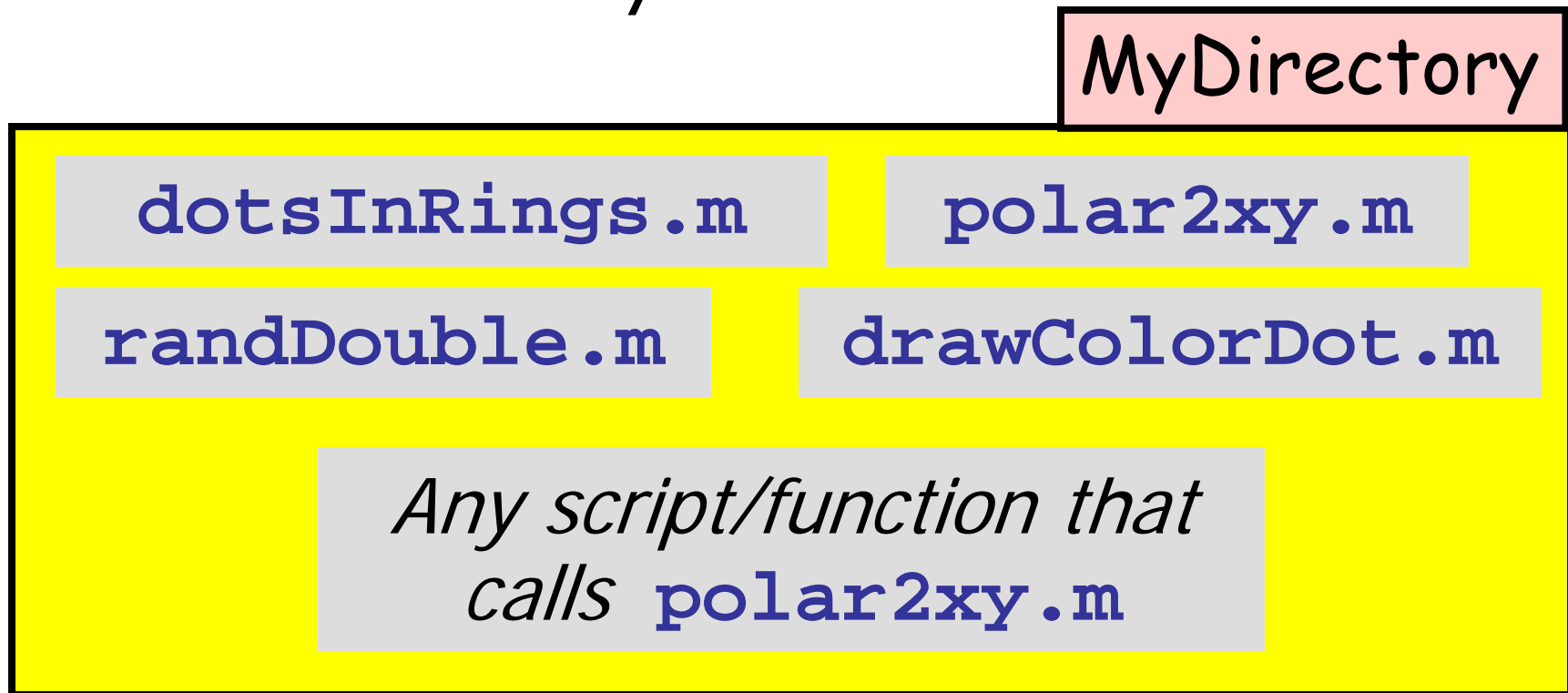 **lookfor <someWord>**

  at the Command Window

- Every function should have a comment block after the function header that says <u>what the function does concisely</u>

Accessing your functions

For now*, put your related functions and scripts in the same directory.

MyDirectory

`dotsInRings.m`   `polar2xy.m`

`randDouble.m`   `drawColorDot.m`

Any script/function that calls `polar2xy.m`

*The `path` function gives greater flexibility

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

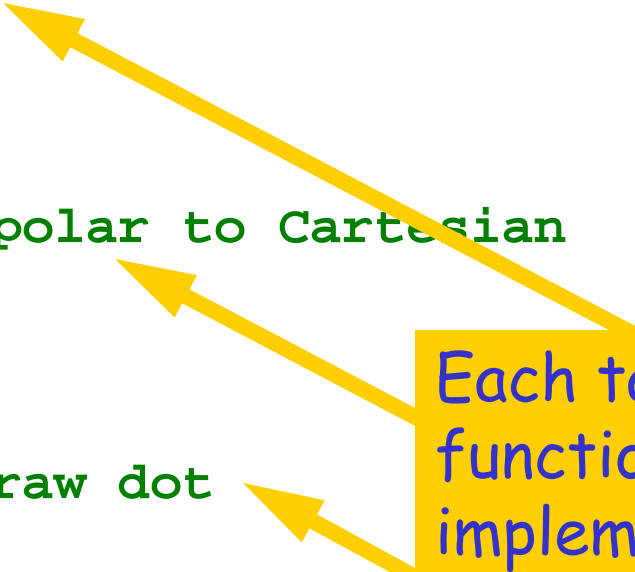→ Facilitate top-down design

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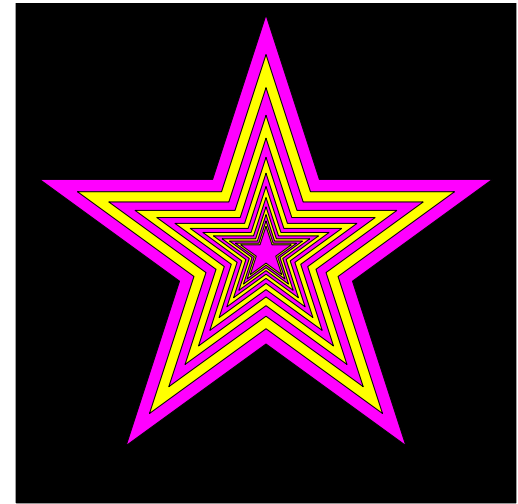
Each task becomes a function that can be implemented and tested independently

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)));
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 and vectors soon.

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

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

<u>During this year</u> :

You write software that makes extensive use of

$$\texttt{EPerimeter(a,b)}$$

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

Software Management

<u>Next year</u>:

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

$$\texttt{EPerimeter(a,b)}$$

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?

A: -3   **B: 3**   **C: error**

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

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

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)
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end
q= p;
```

Command Window Workspace

p	-3

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)
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q= p;
```
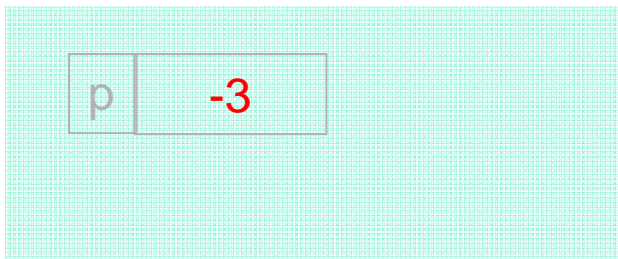
Command Window Workspace

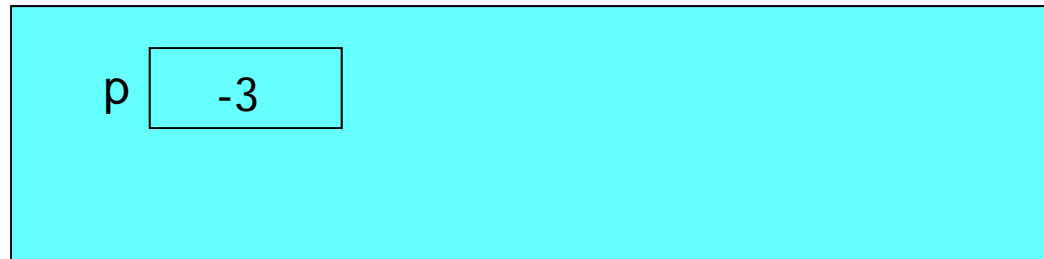| p	-3

What will be printed?

```
% Script file
p= -3;
q= absolute(p);
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```
function q = absolute(p)
% q is the absolute value of p
if (p<0)
   p= -p;
end
q= p;
```

Command Window Workspace

p	-3

Function absolute's Workspace

p [   ]

What will be printed?

```
% Script file
p= -3;
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```
function q = absolute(p)
% q is the absolute value of p
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q= p;
```

Command Window Workspace

p	-3

Function absolute's Workspace

p	-3

What will be printed?

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

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

Command Window Workspace

p	-3

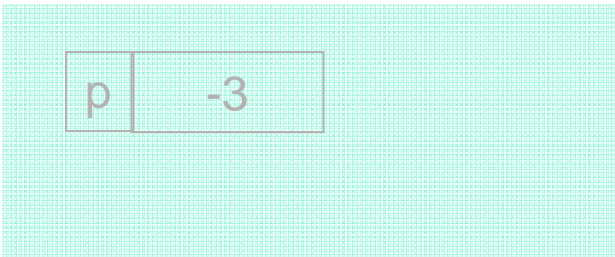Function absolute's Workspace
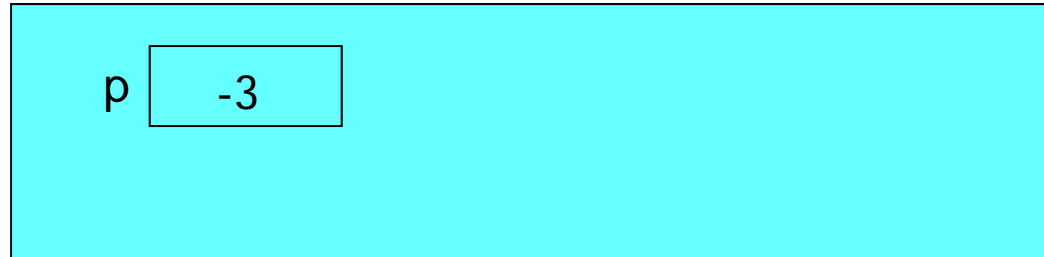
p	-3

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;
```

Command Window Workspace

p	-3

Function absolute's Workspace
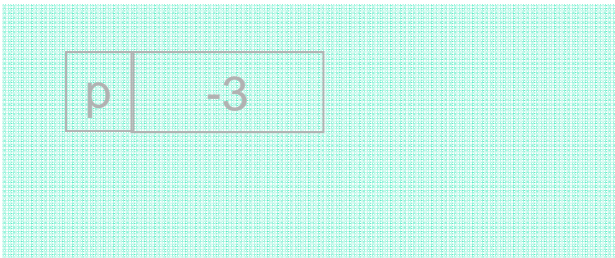
p	-3

What will be printed?

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% 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;
```

Command Window Workspace

p	-3

Function absolute's Workspace

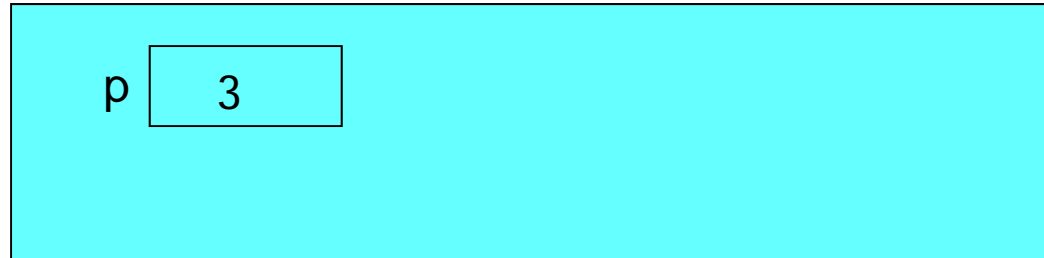| p	3

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;
```

Command Window Workspace

p	-3

Function absolute's Workspace

p	3
q	3

What will be printed?

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

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

Command Window Workspace

p	-3

Function absolute's Workspace

p	3
q	3

What will be printed?

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function q = absolute(p)
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end
q= p;

Command Window Workspace

p | -3
q | 3

Function absolute's Workspace

p | 3
q | 3

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;
```

Command Window Workspace

p	-3
q	3

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;
```
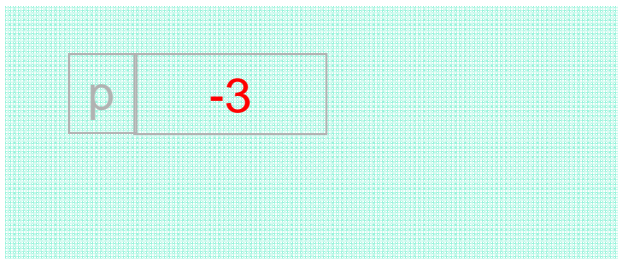
Command Window Workspace

| p | -3 |
| q | 3 |

REVIEW!!!

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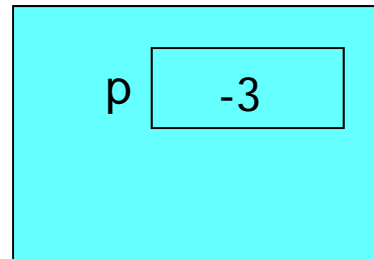p= -3;
q= absolute(p);
disp(p)

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

Command Window Workspace

p	-3

Function

p	-3

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.

Command Window Workspace

p	-3
q	3

Function absolute's Workspace

p	3
q	3

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

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