- 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

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.
…
```

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

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
- 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)));
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.

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?

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 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

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1-d array: **vector**

- An array is a named collection of like data organized into rows or columns
- A 1-d array is a row or a column, called a *vector*
- An *index* identifies the position of a value in a vector

v	.8	.2	1
	1	2	3

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Here are a few different ways to create a vector

```
count= zeros(1,6)
```

Similar functions: **ones**, **rand**

```
a= linspace(10,30,5)
b= 7:-2:0
c= [3 7 2 1]
d= [3; 7; 2]
e= d'
```

count	0	0	0	0	0	0
a	10	15	20	25	30	
b	7	5	3	1		
c	3	7	2	1		

d	3
	7
	2

e	3	7	2

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Start with drawing a single line segment

```
a= 0;  % x-coord of pt 1
b= 1;  % y-coord of pt 1
c= 5;  % x-coord of pt 2
d= 3;  % y-coord of pt 2
plot([a c], [b d], '-*')
```

x-values (a vector)

y-values (a vector)

Line/marker format

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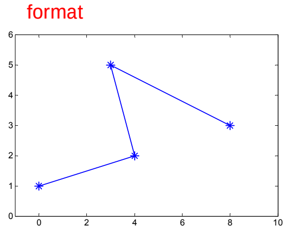
Making an x-y plot

```
a= [0 4 3 8];  % x-coords
b= [1 2 5 3];  % y-coords
plot(a, b, '-*')
```

x-values (a vector)

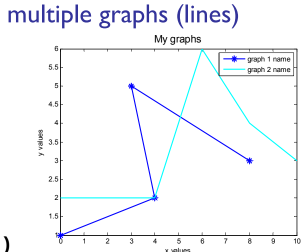
y-values (a vector)

Line/marker format



Making an x-y plot with multiple graphs (lines)

```
a= [0 4 5 8];
b= [1 2 5 3];
f= [0 4 6 8 10];
g= [2 2 6 4  3];
plot(a,b,'-*',f,g,'c')
legend('graph 1 name', 'graph 2 name')
xlabel('x values')
ylabel('y values')
title('My graphs', 'Fontsize',14)
```



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Array index starts at 1

x	5	.4	.91	-4	-1	7
	1	2	3	4	5	6

Let k be the index of vector x, then

- k must be a positive integer
- 1<= k <= length(x)
- To access the k^{th} element: x(k)

Accessing values in a vector

score	93	99	87	80	85	82
	1	*2*	*3*	*4*	*5*	*6*

Given the vector **score** …

```
score(4)= 80;
score(5)= (score(4)+score(5))/2;
k= 1;
score(k+1)= 99;
```

See **plotComparison2.m**

Drawing a polygon (multiple line segments)

```
% Draw a rectangle with the lower-left
% corner at (a,b), width w, height h.
x= [                    ];  % x data
y= [                    ];  % y data
plot(x, y)
```

Fill in the missing vector values!