An Introduction to MATLAB

Day 2

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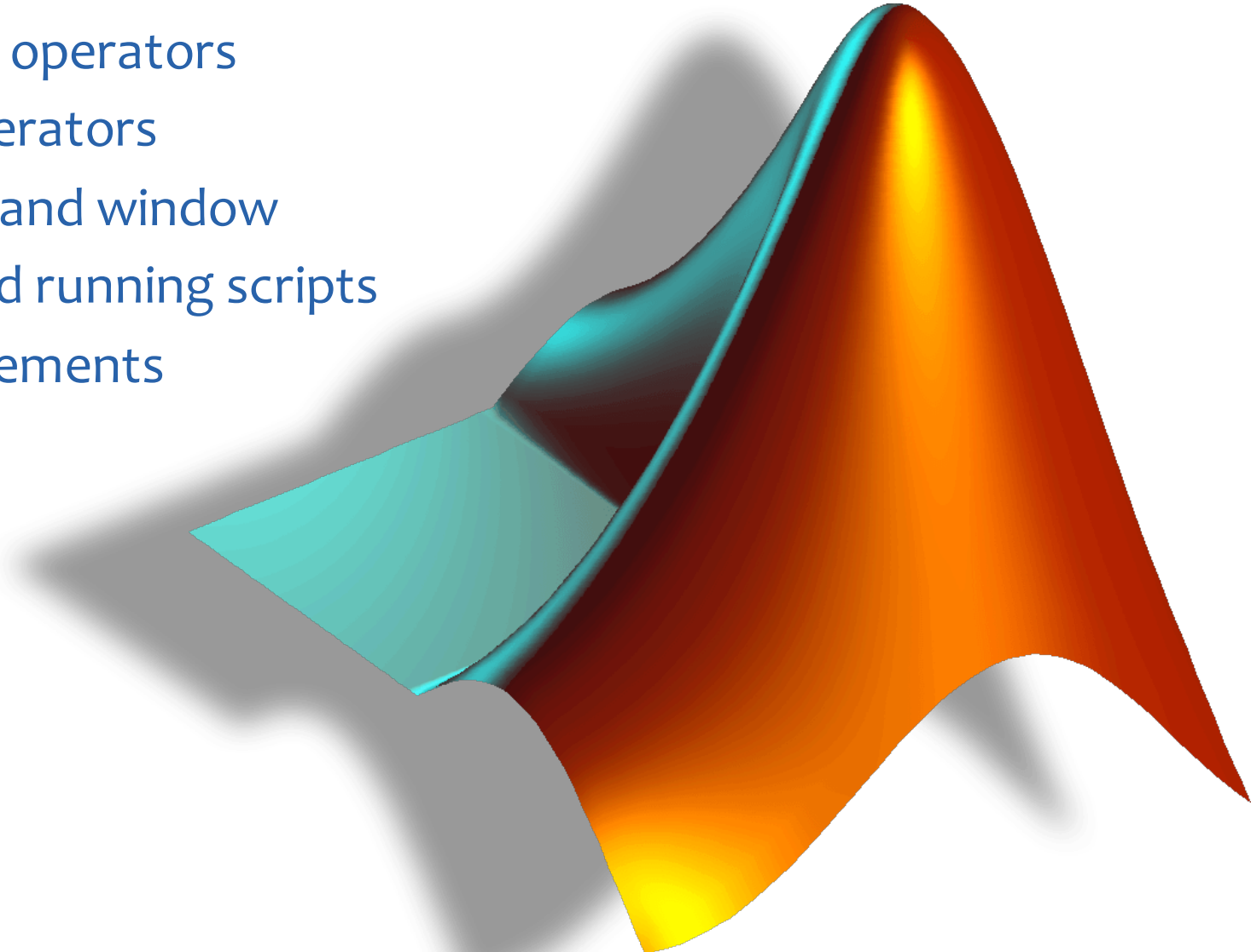
Day 1:

* The development environment
* Variables
* Arithmetic operators
* Logical operators
* The command window
* Writing and running scripts
* if else statements
* for loops



While loops

```
while <expression>
  <statements>
end
```

Editor – /Users/simon/Uni/MATLAB/Workshop/w

whileLoop.m

```
1 -   a = 10;
2     % while loop execution
3 -   while( a < 20 )
4 -     fprintf('value of a: %d\n', a);
5 -     a = a + 1;
6 -   end
```

Command Window

```
>> edit whileLoop.m
>> whileLoop
value of a: 10
value of a: 11
value of a: 12
value of a: 13
value of a: 14
value of a: 15
value of a: 16
value of a: 17
value of a: 18
value of a: 19
fx >>
```

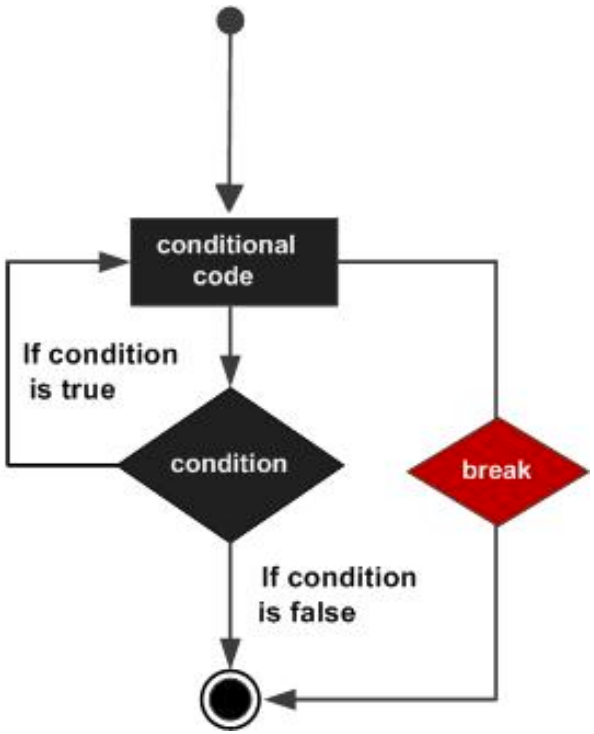
Same result with for loop and while loop

Editor – /Users/simon/Uni/MATLAB/Workshop

whileLoop.m

```
a = 10;
% while loop execution
while( a < 20 )
   fprintf('value of a: %d\n', a);
   a = a + 1;
end
% for loop execution
for b=10:20
    fprintf('value of b: %d\n',b);
end
```

break statements



Editor – /Users/simon/Uni/MATLAB/Workshop/whileLoop.m

whileLoop.m

```
a = 10;
% while loop execution
while (a < 20 )
    fprintf('value of a: %d\n', a);
    a = a+1;
        if( a > 15)
            % terminate the loop using break statement
            break;
        end
end
```

Command Window

```
>> whileLoop
value of a: 10
value of a: 11
value of a: 12
value of a: 13
value of a: 14
value of a: 15
>>
```

A little more about vectors

Reference the ‘i’th element of a vector with

v(i)

```
>> v = [ 1; 2; 3; 4; 5; 6]

v =

     1
     2
     3
     4
     5
     6

>> v(3)

ans =
```

?

A little more about vectors

v(:)

Gets all elements in the vector

V(3:6)

Gets the 3rd to the 6th element

Command Window

```
>> v(:)

ans =

     1
     2
     3
     4
     5
     6

>> v(3:6)

ans =

     3
     4
     5
     6

fx >>
```

A little more about matrices

v(m,n)

Gets the element at

m^{th} row and n^{th} column

Command Window

```
>> a = [ 1 2 3 4 5; 2 3 4 5 6; 3 4 5 6 7; 4 5 6 7 8];
>> a

a =

     1     2     3     4     5
     2     3     4     5     6
     3     4     5     6     7
     4     5     6     7     8

>> a(2,5)

ans =

     6

>>
```

A little more about matrices

Command Window

```
a =

     1     2     3     4     5
     2     3     4     5     6
     3     4     5     6     7
     4     5     6     7     8

>> a(:,4)

ans =

     4
     5
     6
     7

>> a(4,:)

ans =

     4     5     6     7     8

>> |
```

Indexing can be combined with ':'

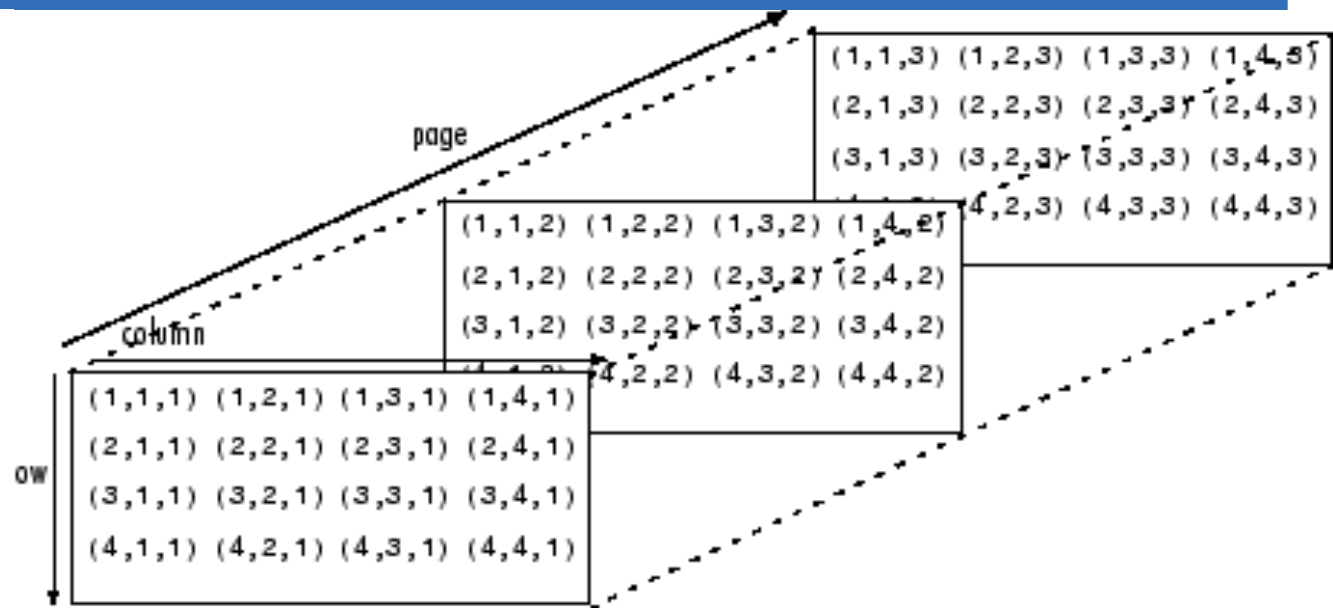
```
>> a(2:3,2:3)

ans =

     3     4
     4     5
```

Convenient matrix creation

```
>> zeros(3)

ans =

     0     0     0
     0     0     0
     0     0     0

>> ones(2,4)

ans =

     1     1     1     1
     1     1     1     1
```

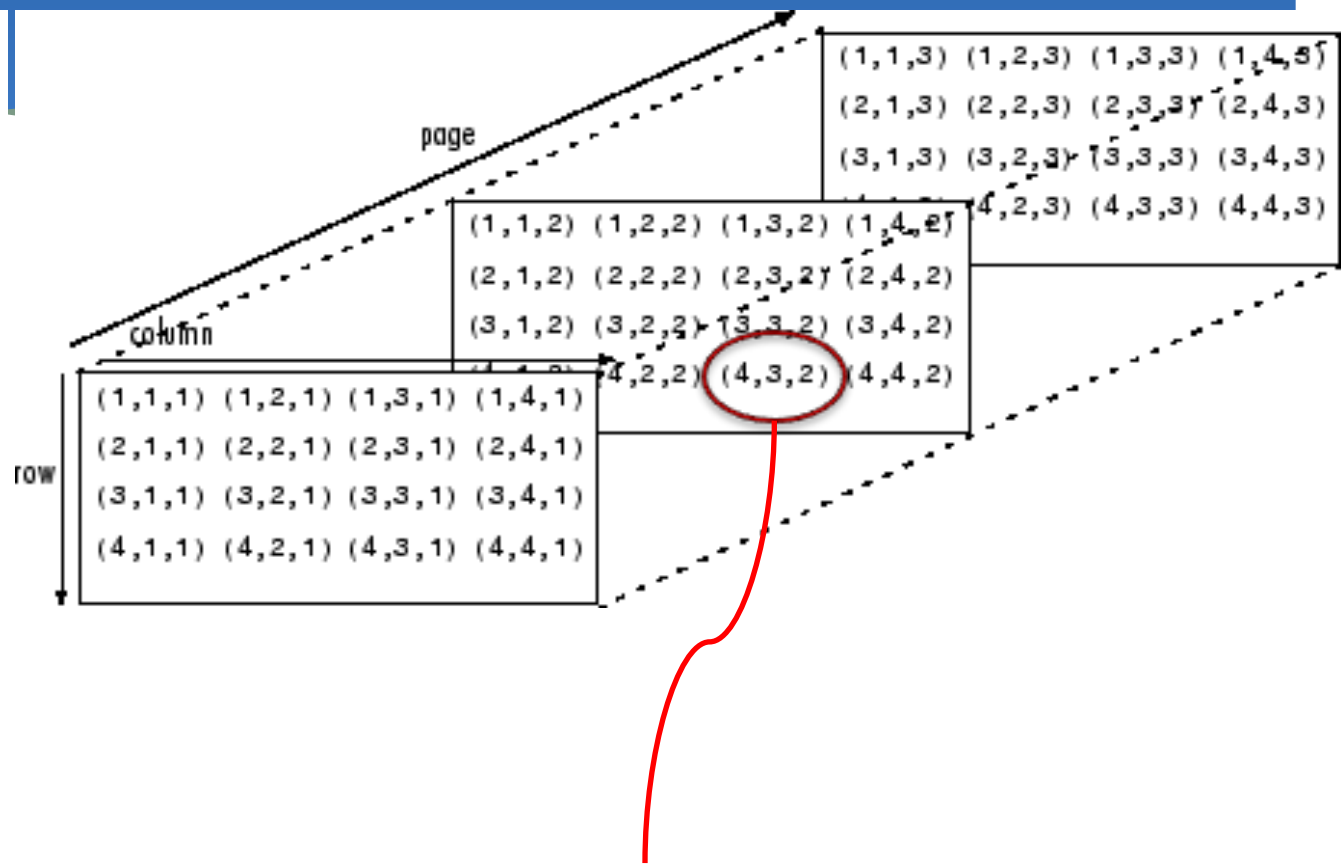
Higher dimensional Matrices

```
>> myMatrix=zeros(4,4,3)

myMatrix(:,:,1) =

     0     0     0     0
     0     0     0     0
     0     0     0     0
     0     0     0     0


myMatrix(:,:,2) =

     0     0     0     0
     0     0     0     0
     0     0     0     0
     0     0     0     0


myMatrix(:,:,3) =

     0     0     0     0
     0     0     0     0
     0     0     0     0
     0     0     0     0
```



Higher dimensional Matrices

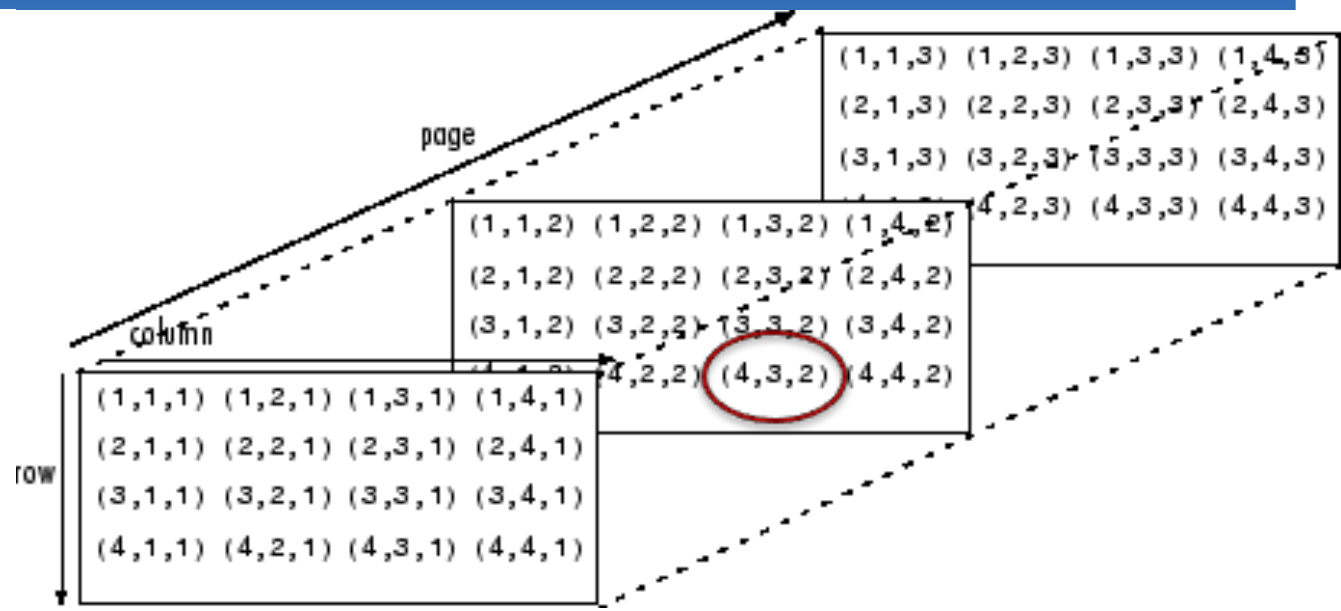
```
>> myMatrix=zeros(4,4,3)

myMatrix(:,:,1) =

     0     0     0     0
     0     0     0     0
     0     0     0     0
     0     0     0     0


myMatrix(:,:,2) =

     0     0     0     0
     0     0     0     0
     0     0     0     0
     0     0     0     0


myMatrix(:,:,3) =

     0     0     0     0
     0     0     0     0
     0     0     0     0
     0     0     0     0
```



How would you change this element to a 7?

Higher dimensional Matrices

```
>> myMatrix(4,3,2)=7

myMatrix(:,:,1) =

     0     0     0     0
     0     0     0     0
     0     0     0     0
     0     0     0     0


myMatrix(:,:,2) =

     0     0     0     0
     0     0     0     0
     0     0     0     0
     0     0     7     0


myMatrix(:,:,3) =

     0     0     0     0
     0     0     0     0
     0     0     0     0
     0     0     0     0
```

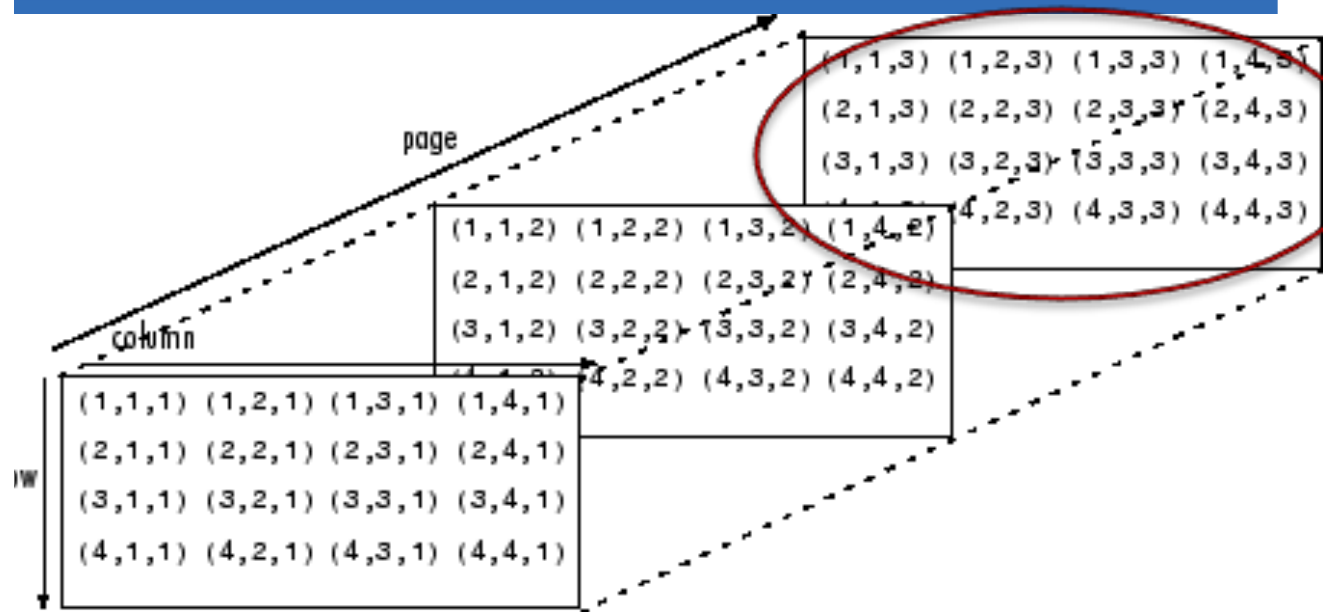


What does myMatrix look like after this command?

```
>> myMatrix(:,:,3)=ones(4)
```

Higher dimensional Matrices

```
>> myMatrix(:,:,3)=ones(4)

myMatrix(:,:,1) =

     0     0     0     0
     0     0     0     0
     0     0     0     0
     0     0     0     0


myMatrix(:,:,2) =

     0     0     0     0
     0     0     0     0
     0     0     0     0
     0     0     7     0


myMatrix(:,:,3) =

     1     1     1     1
     1     1     1     1
     1     1     1     1
     1     1     1     1
```



Sorting

sortingTest.m

```
v = [ 23 45 12 9 5 0 19 17]
sort(v)
m = [2 6 4; 5 3 9; 2 0 1]
sort(m, 1)
sort(m, 2)
```

```
>> sortingTest

v =

    23    45    12     9     5     0    19    17


ans =

     0     5     9    12    17    19    23    45


m =

     2     6     4
     5     3     9
     2     0     1


ans =

     2     0     1
     2     3     4
     5     6     9


ans =

     2     4     6
     3     5     9
     0     1     2
```

Cell Arrays – like matrices but more awesome

We've seen an example before!

Editor – /Users/simon/Uni/MATLAB/Workshop/forLoops.m

ifStatement.m | forLoops.m | forLoopExample.m

```
exp1Genes = {'IL1A','NFKBIA','BCL2','STAT5A','CCL5','MYC','IRF1'};
exp1Results = [4,56,21,12,39,21,3];
threshold = 20;
for i=1:length(exp1Results)
    if(exp1Results(i)>threshold)
        fprintf('Gene %s expression %d\n',exp1Genes{i},exp1Results(i));
    end
end
```

Why did we use a cell array for gene names here?

Cell Arrays – like matrices but more awesome

Matrices are bad for Strings

```
>> geneNames = ['IL1A', 'NFKBIA', 'BCL2', 'STAT5A', 'CCL5']

geneNames =

IL1ANFKBIABCL2STAT5ACCL5

>> geneNames = ['IL1A'; 'NFKBIA'; 'BCL2'; 'STAT5A'; 'CCL5']
Error using vertcat
Dimensions of matrices being concatenated are not consistent.

>> geneNames = ['IL1A  '; 'NFKBIA'; 'BCL2  '; 'STAT5A'; 'CCL5  ']

geneNames =

IL1A
NFKBIA
BCL2
STAT5A
CCL5
```

Cell Arrays – like matrices but more awesome

Can be initiated with

cell(m,n)

```
>> c = cell(2, 5);
>> c = {'IL1A', 'NFKBIA', 'BCL2', 'STAT5A', 'CCL5'; 4,56,21,12,39}

c =

    'IL1A'    'NFKBIA'    'BCL2'    'STAT5A'    'CCL5'
    [   4]    [    56]    [  21]    [    12]    [  39]
```

Cell Arrays – beware of the difference between () and {}

```
c =

    'IL1A'    'NFKBIA'    'BCL2'    'STAT5A'    'CCL5'
    [   4]    [    56]    [  21]    [    12]    [  39]
```

c(m,n) refers to sets of cells

```
>> c(:,2:3)

ans =

    'NFKBIA'    'BCL2'
    [    56]    [  21]
```

c{m,n} refers to the data within the cells

```
>> c{:,2:3}

ans =

NFKBIA


ans =

    56


ans =

BCL2


ans =

    21
```

String Comparisons

Editor – /Users/simon/UniNew/MATLAB/Workshop/forLoops.m

+8 | SolveBigAllSpecies.m | initial_parameters8.m | MatFile.m | mlprintjob.m | forLoops.m

```
exp1Genes = {'IL1A','NFKBIA','BCL2','IRF1','STAT5A','CCL5','MYC'};
exp1Results = [4,56,21,3,12,39,21];
threshold = 20;
geneOfInterest='IRF1';
for i=1:length(exp1Results)
    if(exp1Results(i)>threshold)
        fprintf('Gene %s expression %d\n',exp1Genes{i},exp1Results(i));
    end
    if(strcmp(exp1Genes{i},geneOfInterest))
        fprintf('Expression of %s: %d\n',geneOfInterest,exp1Results(i));
    end
end
fprintf('Expression of %s: %d\n',geneOfInterest,exp1Results(i));
```

Command Window

```
>> forLoops
Gene NFKBIA expression 56
Gene BCL2 expression 21
Expression of IRF1: 3
Gene CCL5 expression 39
Gene MYC expression 21
Expression of IRF1: 21
>>
```

Time for Functions!

* 3 Ways of running code
  * Command Window ✓
  * Scripts ✓
  * Functions

m-files

Defining Functions

function [outputs] = functionName (inputs)

Sometimes inputs are called “arguments”.

Our First Function

Editor – /Users/simon/Uni/MATLAB/Workshop/reverseSeq.m

forLoops.m | reverseSeq.m

```
function outSeq = reverseSeq(seq)
    %This function returns the reverse of an input sequence
    outSeq=seq(end:-1:1);
```

Command Window

```
>> edit reverseSeq.m
>> reverseSeq('TCGCG')

ans =

GCGCT
```

+8 SolveBigAllSpecies.m | initial_parameters8.m | MatFile.m | mlprintjob.m | forLoops.m

```
exp1Genes = {'IL1A','NFKBIA','BCL2','IRF1','STAT5A','CCL5','MYC'};
exp1Results = [4,56,21,3,12,39,21];
threshold = 20;
geneOfInterest='IRF1';
for i=1:length(exp1Results)
    if(exp1Results(i)>threshold)
        fprintf('Gene %s expression %d\n',exp1Genes{i},exp1Results(i));
    end
    if(strcmp(exp1Genes{i},geneOfInterest))
        fprintf('Expression of %s: %d\n',geneOfInterest,exp1Results(i));
    end
end
fprintf('Expression of %s: %d\n',geneOfInterest,exp1Results(i));
```

printGeneExpression.m* | printGeneExpressionFromFile.m | forLoops.m

```
function out = printGeneExpression(exp1Genes, exp1Results, geneOfInterest, threshold)
    %Function prints gene expression information for a list of genes over a
    %given threshold
    %Returns the expression value from a gene of interest
    out='Gene Not Found';
    for i=1:length(exp1Results)
        if(exp1Results(i)>threshold)
            fprintf('Gene %s expression %d\n',exp1Genes{i},exp1Results(i));
        end
        if(strcmp(exp1Genes{i},geneOfInterest))
            fprintf('Expression of %s: %d\n',geneOfInterest,exp1Results(i));
            out = exp1Results(i);
        end
    end
```

printGeneExpression.m* | printGeneExpressionFromFile.m | forLoops.m

```
function out = printGeneExpression(exp1Genes, exp1Results, geneOfInterest, threshold)
    %Function prints gene expression information for a list of genes over a
    %given threshold
    %Returns the expression value from a gene of interest
    out='Gene Not Found';
    for i=1:length(exp1Results)
        if(exp1Results(i)>threshold)
            fprintf('Gene %s expression %d\n',exp1Genes{i},exp1Results(i));
        end
        if(strcmp(exp1Genes{i},geneOfInterest))
            fprintf('Expression of %s: %d\n',geneOfInterest,exp1Results(i));
            out = exp1Results(i);
        end
    end
```

```
>> genes = {'IL1A','NFKBIA','BCL2','STAT5A','CCL5','MYC','IRF1'};
>> values = [4,56,21,12,39,21,3];
>> geneOfInterestValue = printGeneExpression(genes,values,'IRF1',20)
Gene NFKBIA expression 56
Gene BCL2 expression 21
Gene CCL5 expression 39
Gene MYC expression 21
Expression ofIRF1 3

geneOfInterestValue =

     3
```

Getting Help

```
>> help printGeneExpression
 Function prints gene expression information for a list of genes over a
 given threshold
 Returns the expression value from a gene of interest
```

```
>> help max
 max    Largest component.
    For vectors, max(X) is the largest element in X. For matrices,
    max(X) is a row vector containing the maximum element from each
    column. For N-D arrays, max(X) operates along the first
    non-singleton dimension.
```

Google!!!

Working with files

```
>> url='http://signalingsystems.ucla.edu/users/Simon/example.jpg';
>> imageFile='example.jpg';
>> urlwrite(url,imageFile);
>> A=imread(imageFile);
>> image(A);
```

Working with (more sensible) files

Download example file:

http://www.signalingsystems.ucla.edu/users/Simon/experiment1.txt

Editor – /Users/simon/Uni/MATLAB/Workshop/printGeneExpressionFromFile.m

printGeneExpressionFromFile.m | printGeneExpression.m

```
function out = printGeneExpressionFromFile(inputFileName, geneOfInterest, threshold)
    %Function prints gene expression information for a list of genes from a file
    %prints gene informaton for genes over a given threshold
    %Returns the expression value from a gene of interest
    delimiter='\t'; %tab delimeter
    headerLines=1;%titles are on first line

    A=importdata(inputFileName,delimiter,headerLines);
    exp1Genes=A.textdata(2:end,1);
    exp1Results=A.data;

    fprintf('%s loaded. %d genes.',inputFileName,length(A.data));

    %call function to print gene information
    out = printGeneExpression(exp1Genes,exp1Results,geneOfInterest,threshold);
```

Working with (more sensible) files

Download example file:

http://www.signalingsystems.ucla.edu/users/Simon/experiment1.txt

Editor – /Users/simon/Uni/MATLAB/Workshop/printGeneExpressionFromFile.m

printGeneExpressionFromFile.m | printGeneExpression.m

```
function out = printGeneExpressionFromFile(inputFileName, geneOfInterest, threshold)
    %Function prints gene expression information for a list of genes from a file
    %prints gene informaton for genes over a given threshold
    %Returns the expression value from a gene of interest
    delimiter='\t'; %tab delimeter
    headerLines=1;%titles are on first line

    A=importdata(inputFileName,delimiter,headerLines);
    exp1Genes=A.textdata(2:end,1);
    exp1Results=A.data;

    fprintf('%s loaded. %d genes.\n',inputFileName,length(A.data));

    %call function to print gene information
    out = printGeneExpression(exp1Genes,exp1Results,geneOfInterest,threshold);
```

Command Window

```
>> printGeneExpressionFromFile('experiment1.txt','CCL5',20)
```

Tidying up output

```
Gene IL-23A (p19) expression 2.761789e+01
Gene IL-27 (p28) expression 2.827399e+01
Gene EBI3/IL-27B expression 3.333691e+01
Gene beta-Interferon expression 2.658134e+01
```

```
Gene IL-23A (p19) expression 27.62
Gene IL-27 (p28) expression 28.27
Gene EBI3/IL-27B expression 33.34
Gene beta-Interferon expression 26.58
```

printGeneExpression.m* | printGeneExpressionFromFile.m | forLoops.m

```
function out = printGeneExpression(exp1Genes, exp1Results, geneOfInterest, threshold)
    %Function prints gene expression information for a list of genes over a
    %given threshold
    %Returns the expression value from a gene of interest
    out='Gene Not Found';
    for i=1:length(exp1Results)
        if(exp1Results(i)>threshold)
            fprintf('Gene %s expression %.2f\n',exp1Genes{i},exp1Results(i));
        end
        if(strcmp(exp1Genes{i},geneOfInterest))
            fprintf('Expression of %s: %d\n',geneOfInterest,exp1Results(i));
            out = exp1Results(i);
        end
    end
```

Writing to files

```
fileIdentifier = fopen('filename','w');

fprintf(fileIdentifier, 'someText');

fclose(fid);
```

Changing our functions to write to a file

Editor – /Users/simon/UniNew/MATLAB/Workshop/printGeneExpressionFromFile.m

printGeneExpression.m | printGeneExpressionFromFile.m

```
function out = printGeneExpressionFromFile(inputFileName, outputFileName, geneOfInterest, threshold)
    %Function prints gene expression information for a list of genes from a file
    %prints gene informaton for genes over a given threshold
    %Returns the expression value from a gene of interest
    delimiter='\t'; %tab delimeter
    headerLines=1;%titles are on first line

    A=importdata(inputFileName,delimiter,headerLines);
    exp1Genes=A.textdata(2:end,1);
    exp1Results=A.data;

    fprintf('%s loaded. %d genes.\n',inputFileName,length(A.data));

    %call function to print gene information
    out = printGeneExpression(exp1Genes,exp1Results,geneOfInterest,threshold, outputFileName);
```

Editor – /Users/simon/UniNew/MATLAB/Workshop/printGeneExpressionFromFile.m

printGeneExpression.m | printGeneExpressionFromFile.m

```
function out = printGeneExpressionFromFile(inputFileName, outputFileName, geneOfInterest, threshold)
    %Function prints gene expression information for a list of genes from a file
    %prints gene informaton for genes over a given threshold
    %Returns the expression value from a gene of interest
    delimiter='\t'; %tab delimeter
    headerLines=1;%titles are on first line

    A=importdata(inputFileName,delimiter,headerLines);
    exp1Genes=A.textdata(2:end,1);
    exp1Results=A.data;

    fprintf('%s loaded. %d genes.\n',inputFileName,length(A.data));

    %call function to print gene information
    out = printGeneExpression(exp1Genes,exp1Results,geneOfInterest,threshold, outputFileName);
```

printGeneExpression.m | printGeneExpressionFromFile.m

```
function out = printGeneExpression(exp1Genes, exp1Results, geneOfInterest, threshold, outputFileName)
    %Function prints gene expression information for a list of genes over a
    %given threshold
    %Returns the expression value from a gene of interest
    fid=fopen(outputFileName,'w');
    out='Gene Not Found';
    for i=1:length(exp1Results)
        if(exp1Results(i)>threshold)
            fprintf(fid,'%s\t%.2f\n',exp1Genes{i},exp1Results(i));
        end
        if(strcmp(exp1Genes{i},geneOfInterest))
            fprintf(fid,'Expression of %s: %d\n',geneOfInterest,exp1Results(i));
            out = exp1Results(i);
        end
    end
    fclose(fid);
```

Changing our functions to write to a file

printGeneExpression.m | printGeneExpressionFromFile.m

```
function out = printGeneExpression(exp1Genes, exp1Results, geneOfInterest, threshold, outputFileName)
    %Function prints gene expression information for a list of genes over a
    %given threshold
    %Returns the expression value from a gene of interest
    fid=fopen(outputFileName,'w');
    out='Gene Not Found';
    for i=1:length(exp1Results)
        if(exp1Results(i)>threshold)
            fprintf(fid,'%s\t%.2f\n',exp1Genes{i},exp1Results(i));
        end
        if(strcmp(exp1Genes{i},geneOfInterest))
            fprintf(fid,'Expression of %s: %d\n',geneOfInterest,exp1Results(i));
            out = exp1Results(i);
        end
    end
    fclose(fid);
```

```
>> printGeneExpressionFromFile('experiment1.txt','experimentOutput.txt','CCL5',20)
experiment1.txt loaded. 59 genes.
Expression ofCCL5 3.84

ans =

        3.84
```

Open ‘experimentOutput.txt’ in excel