

- Today's Lecture:

- Cell arrays
- File input/output

- Announcements:

- **Lab 3 exercise** is very important for A2 and Test2. Make sure that you learn that material
- **Test 1** (second run, optional) Thursday 9/20 3:35p in HLS B14
- **Assignment 2** due Thursday 9/27 at 11:59pm

Matrix vs. Cell Array

Vectors and matrices store values of the same type in all components

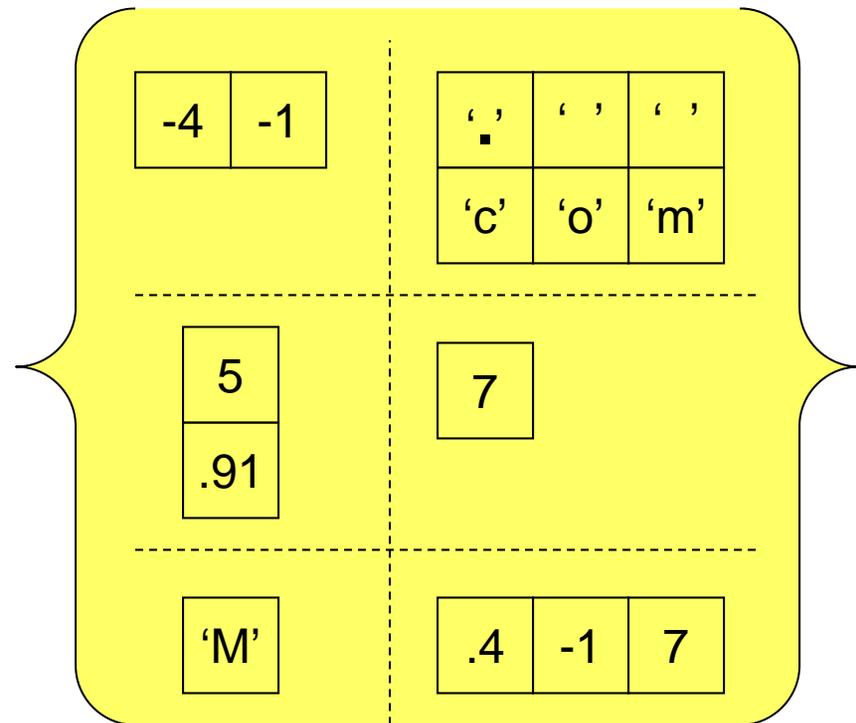
3.1
2
-1
9
1.1

5 x 1 matrix

'c'	'o'	'm'	' '	's'
'1'	'1'	'1'	'2'	' '
'M'	'a'	't'	' '	' '
' '	' '	'L'	'A'	'B'

4 x 5 matrix

A cell array is a special array whose individual components may contain different types of data



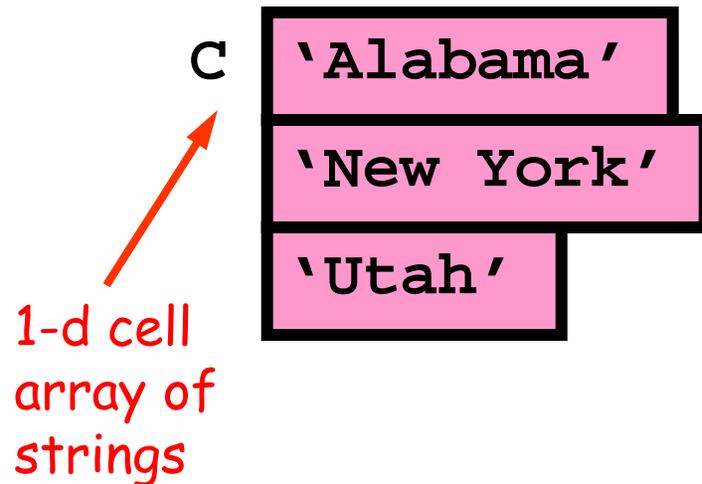
3 x 2 cell array

Cell Arrays of Strings

```
C = { 'Alabama', 'New York', 'Utah' }
```



```
C = { 'Alabama'; 'New York'; 'Utah' }
```



Contrast with
2-d array of characters

```
M = [ 'Alabama'; ...  
      'New York'; ...  
      'Utah' ]
```

	'A'	'l'	'a'	'b'	'a'	'm'	'a'	' '
M	'N'	'e'	'w'	' '	'Y'	'o'	'r'	'k'
	'U'	't'	'a'	'h'	' '	' '	' '	' '

Use braces { } for creating and addressing cell arrays

Matrix

- Create

```
m = [ 5, 4 ; ...  
      1, 2 ; ...  
      0, 8 ]
```

- Addressing

```
m(2,1) = pi
```

Cell Array

- Create

```
C = { ones(2,2), 4 ; ...  
      'abc' , ones(3,1) ; ...  
      9 , 'a cell' }
```

- Addressing

```
C{2,1} = 'ABC'  
C{3,2} = pi  
disp(C{3,2})
```

Creating cell arrays...

```
C = {'Oct', 30, ones(3,2)};
```

is the same as

```
C = cell(1,3); % not necessary
```

```
C{1} = 'Oct';
```

```
C{2} = 30;
```

```
C{3} = ones(3,2);
```

You can assign the empty cell array: `D = {}`

Example: Build a cell array of Roman numerals
for 1 to 3999

`C{1} = 'I'`

`C{2} = 'II'`

`C{3} = 'III'`

:

`C{2007} = 'MMVII'`

:

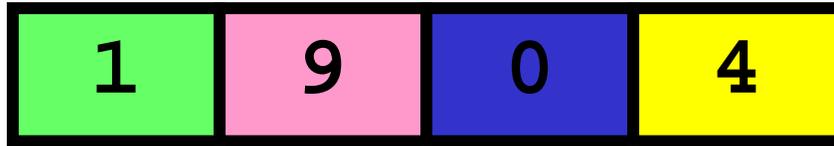
`C{3999} = 'MMMCMXCIX'`

Example

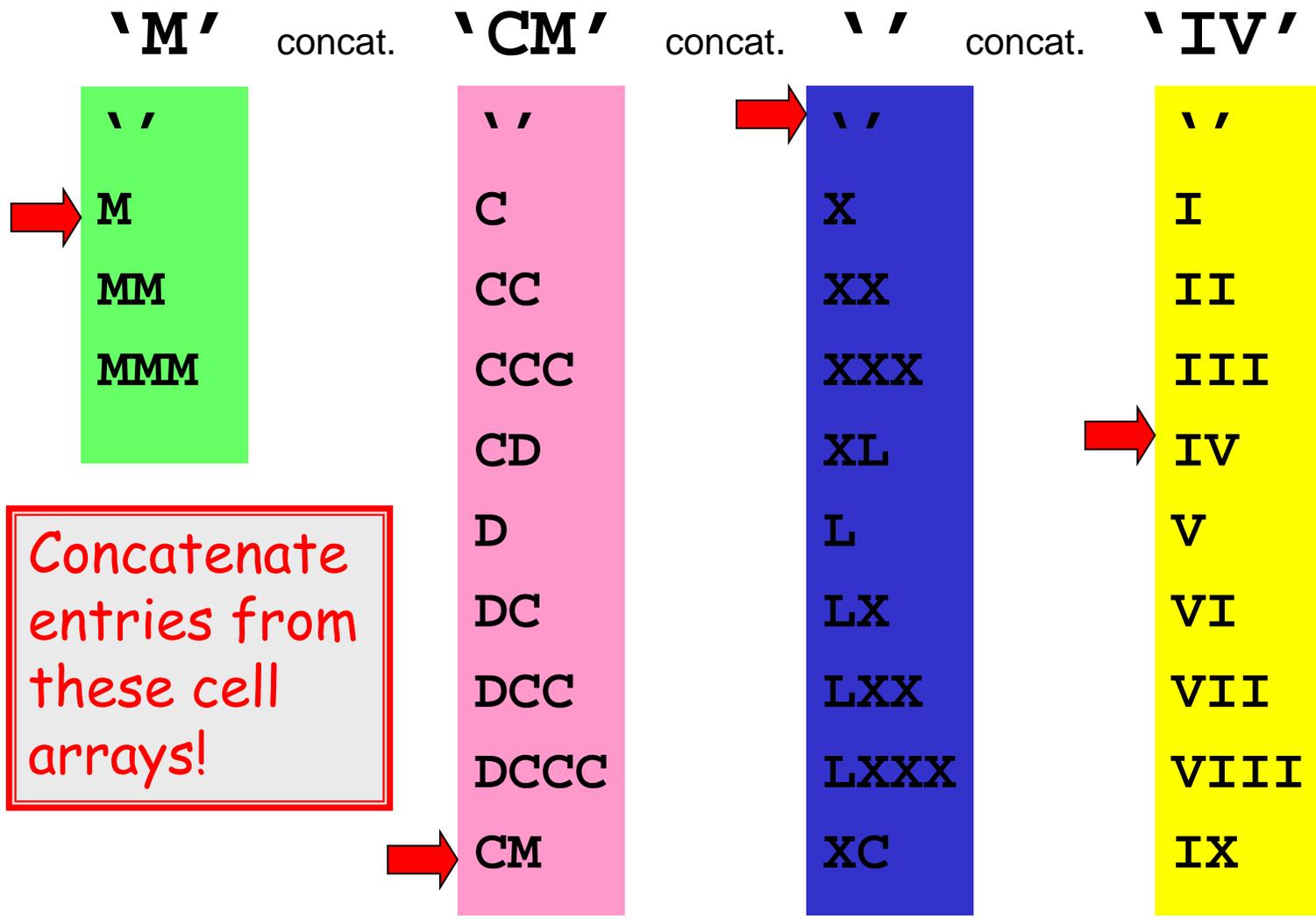
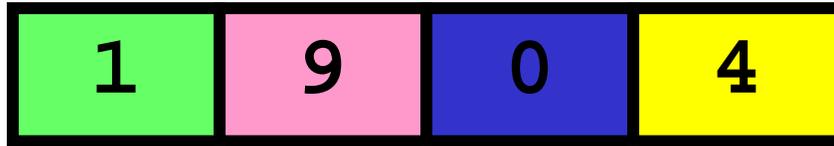
$$1904 = 1*1000 + 9*100 + 0*10 + 4*1$$

$$= \quad M \quad \quad CM \quad \quad \quad IV$$

$$= \quad MCMIV$$



MCMIV



Concatenate entries from these cell arrays!

Ones-Place Conversion

```
function r = Ones2R(x)
% x is an integer that satisfies
%     0 <= x <= 9
% r is the Roman numeral with value x.

Ones = {'I', 'II', 'III', 'IV', ...
        'V', 'VI', 'VII', 'VIII', 'IX'};

if x==0
    r = '';
else
    r = Ones{x};
end
```

Ones-Place Conversion

```
function r = Ones2R(x)
% x is an integer that satisfies
%     0 <= x <= 9
% r is the Roman numeral with value x.

Ones = {'I', 'II', 'III', 'IV', ...
        'V', 'VI', 'VII', 'VIII', 'IX'};

if x==0
    r = '';
else
    r = Ones{x};
end
```

Similarly, we can implement these functions:

```
function r = Tens2R(x)
% x is an integer that satisfies
%     0 <= x <= 9
% r is the Roman numeral with value 10*x.
```

```
function r = Hund2R(x)
% x is an integer that satisfies
%     0 <= x <= 9
% r is the Roman numeral with value 100*x
```

```
function r = Thou2R(x)
% x is an integer that satisfies
%     0 <= x <= 3
% r is the Roman numeral with value 1000*x
```

Now we can build the Roman numeral cell array for 1,...,3999

```
for a = 0:3
    for b = 0:9
        for c = 0:9
            for d = 0:9
                n = a*1000 + b*100 + c*10 + d;
                if n>0
                    C{n} = [Thou2R(a) Hund2R(b)...
                            Tens2R(c) Ones2R(d)];
                end
            end
        end
    end
end
end
```

Now we can build the Roman numeral cell array for 1,...,3999

```
for a = 0:3 % possible values in thous place
  for b = 0:9 % values in hundreds place
    for c = 0:9 % values in tens place
      for d = 0:9 % values in ones place
        n = a*1000 + b*100 + c*10 + d;
        if n>0
          C{n} = [Thou2R(a) Hund2R(b)...
                  Tens2R(c) Ones2R(d)];
        end
      end
    end
  end
end
```

The n^{th} component of cell array C

Four strings concatenated together

Example: subset of clicker IDs

IDs

```
['d091314'; ...  
'h134d83'; ...  
'h4567s2'; ...  
'fr83209']
```

Find subset that
begins with 'h'



L

```
{'h134d83', ...  
'h4567s2'}
```

```
L= {};  
k= 0;  
for r=1:size(IDs,1)  
    if IDs(r,1)=='h'  
        k= k+1;  
        L{k }= IDs(r,:);  
    end  
end
```

Directly assign into a
particular cell—good!

```
L= {};  
  
for r=1:size(ID,1)  
    if IDs(r,1)=='h'  
  
        L= [L, IDs(r,:)];  
    end  
end
```

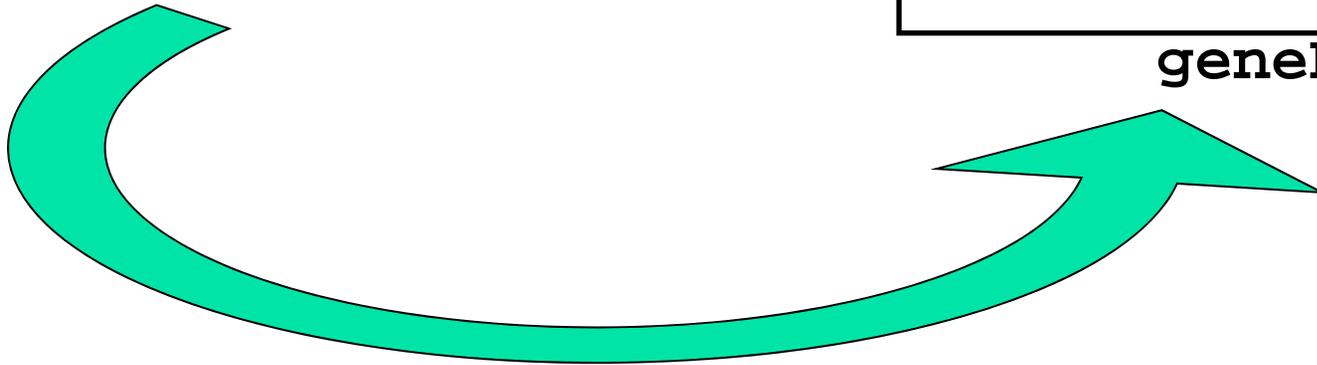
Concatenate cells or
cell arrays—prone to
problems!

Example: Write a cell array of gene sequences to a file

z
{
'GATTTCGAG'
'GAGCCACTGGTC'
'ATAGATCCT'
}

```
GATTTCGAG  
GAGCCACTGGTC  
ATAGATCCT
```

geneData.txt



A 3-step process to
read data from a file or
write data to a file

1. (Create and) **open** a file
2. **Read** data from or **write** data to the file
3. **Close** the file

I. Open a file

```
fid = fopen( 'geneData.txt' , 'w' );
```

An open file has a file ID, here stored in variable **fid**

Name of the file (created and) opened. **txt** and **dat** are common file name extensions for plain text files

Built-in function to open a file

'w' indicates that the file is to be opened for writing

Use 'a' for appending

2. Write (print) to the file

```
fid = fopen( 'geneData.txt', 'w' );  
  
for i=1:length(Z)  
    fprintf(      '%s\n', Z{i} );  
end
```

2. Write (print) to the file

```
fid = fopen( 'geneData.txt', 'w' );
```

```
for i=1:length(Z)
```

```
    fprintf(fid, '%s\n', Z{i});
```

```
end
```

Printing is to be done to the file with ID **fid**

Substitution sequence specifies the *string* format (followed by a new-line character)

The **i**th item in cell array **Z**

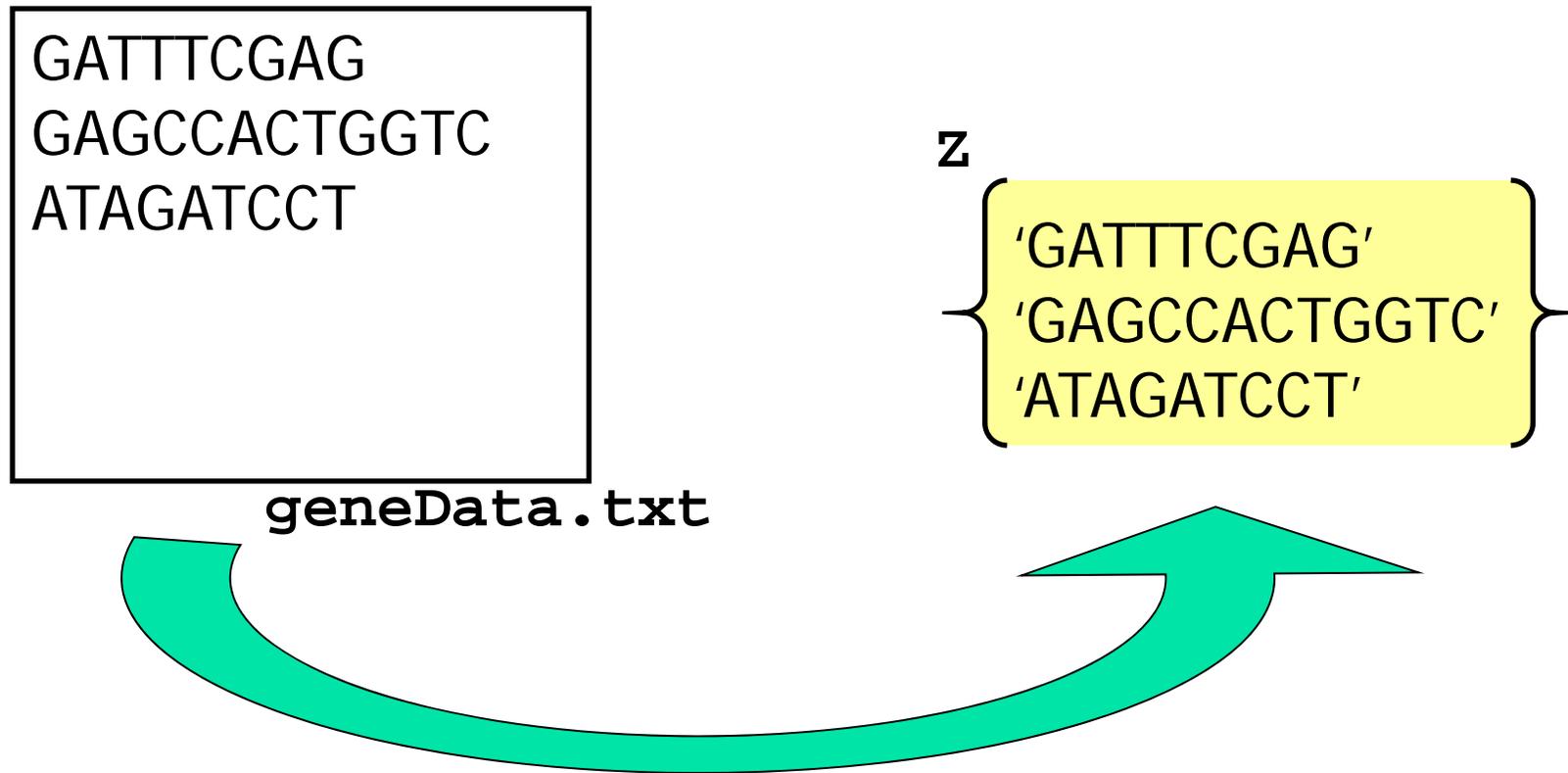
3. Close the file

```
fid = fopen('geneData.txt' , 'w');  
  
for i=1:length(Z)  
    fprintf(fid, '%s\n', Z{i});  
end  
  
fclose(fid);
```

```
function cellArray2file(CA, fname)
% CA is a cell array of strings.
% Create a .txt file with the name
% specified by the string fname.
% The i-th line in the file is CA{i}

fid= fopen([fname '.txt'], 'w');
for i= 1:length(CA)
    fprintf(fid, '%s\n', CA{i});
end
fclose(fid);
```

Reverse problem: Read the data in a file line-by-line and store the results in a cell array



How are lines separated?
How do we know when there are no more lines?

In a file there are hidden “markers”

```
GATTTCGAG ●  
GAGCCACTGGTC ●  
ATAGATCCT ●  
■
```

geneData.txt

- Carriage return marks the end of a line

- eof marks the end of a file

Read data from a file

1. **Open** a file
2. **Read** it line-by-line until eof
3. **Close** the file

I. Open the file

```
fid = fopen( 'geneData.txt', 'r' );
```

An open file has a file ID, here stored in variable **fid**

Built-in function to open a file

Name of the file opened. **txt** and **dat** are common file name extensions for plain text files

'**r**' indicates that the file has been opened for reading

2. Read each line and store it in cell array

```
fid = fopen('geneData.txt', 'r');
```

```
k = 0;
```

```
while ~feof(fid)
```

False until end-of-file is reached

```
    k = k + 1;
```

```
    z{k} = fgetl(fid);
```

```
end
```

Get the next line

3. Close the file

```
fid = fopen('geneData.txt', 'r');
```

```
k= 0;
```

```
while ~feof(fid)
```

```
    k= k+1;
```

```
    z{k}= fgetl(fid);
```

```
end
```

```
fclose(fid);
```

```
function CA = file2cellArray(fname)
% fname is a string that names a .txt file
%   in the current directory.
% CA is a cell array with CA{k} being the
%   k-th line in the file.

fid= fopen([fname '.txt'], 'r');
k= 0;
while ~feof(fid)
    k= k+1;
    CA{k}= fgetl(fid);
end
fclose(fid);
```

A Detailed Read-File Example

From the protein database at

<http://www.rcsb.org>

we download the file `1b18.dat` which encodes the amino acid information for the protein with the same name. We want the xyz coordinates of the protein's "backbone."

The file has a long “header”

```
HEADER      MEMBRANE PROTEIN                      23-JUL-98    1BL8
TITLE       POTASSIUM CHANNEL (KCSA) FROM STREPTOMYCES LIVIDANS
COMPND      MOL_ID: 1;
COMPND      2 MOLECULE: POTASSIUM CHANNEL PROTEIN;
COMPND      3 CHAIN: A, B, C, D;
COMPND      4 ENGINEERED: YES;
COMPND      5 MUTATION: YES
SOURCE      MOL_ID: 1;
SOURCE      2 ORGANISM_SCIENTIFIC: STREPTOMYCES LIVIDANS;
```

Need to read past hundreds of lines
that are not relevant to us.

Eventually, the xyz data is reached...

```
MTRIX1  2 -0.736910 -0.010340  0.675910      112.17546      1
MTRIX2  2  0.004580 -0.999940 -0.010300       53.01701      1
MTRIX3  2  0.675980 -0.004490  0.736910     -43.35083      1
MTRIX1  3  0.137220 -0.931030  0.338160       80.28391      1
MTRIX2  3  0.929330  0.002860 -0.369240     -33.25713      1
MTRIX3  3  0.342800  0.364930  0.865630     -31.77395      1
```

```
ATOM      1  N   ALA  A   23      65.191  22.037  48.576  1.00181.62      N
ATOM      2  CA  ALA  A   23      66.434  22.838  48.377  1.00181.62      C
ATOM      3  C   ALA  A   23      66.148  24.075  47.534  1.00181.62      C
```



**Signal: Lines
that begin with
'ATOM'**



x



y



z

Where exactly are the xyz data?

1-4

14-15

33-38 41-46 49-54



Column nos.
of interest

ATOM	14	N	HIS	A	25	68.656	24.973	44.142	1.00128.26	N
● ATOM	15	CA	HIS	A	25	69.416	24.678	42.939	1.00128.26	C
ATOM	16	C	HIS	A	25	68.843	23.458	42.227	1.00128.26	C
ATOM	17	O	HIS	A	25	68.911	23.354	41.007	1.00128.26	O
ATOM	18	CB	HIS	A	25	70.881	24.416	43.300	1.00154.92	C
ATOM	19	CG	HIS	A	25	71.188	22.977	43.573	1.00154.92	C
ATOM	20	ND1	HIS	A	25	71.886	22.184	42.689	1.00154.92	N
ATOM	21	CD2	HIS	A	25	70.877	22.182	44.625	1.00154.92	C
ATOM	22	CE1	HIS	A	25	71.993	20.963	43.183	1.00154.92	C
ATOM	23	NE2	HIS	A	25	71.388	20.935	44.356	1.00154.92	N
ATOM	24	N	TRP	A	26	68.271	22.546	43.005	1.00 87.09	N
● ATOM	25	CA	TRP	A	26	67.702	21.311	42.475	1.00 87.09	C
ATOM	26	C	TRP	A	26	66.187	21.378	42.339	1.00 87.09	C
ATOM	27	O	TRP	A	26	65.577	20.508	41.718	1.00 87.09	O

x

y

z

Just getting what you need from a data file

- Read past all the header information
- When you come to the lines of interest, collect the xyz data
 - Line starts with 'ATOM'
 - Cols 14-15 is 'CA'

```
fid = fopen('1bl8.dat', 'r'); ←
x=[];y=[];z=[];
while ~feof(fid)
    s = fgetl(fid);
    if strcmp(s(1:4), 'ATOM')
        if strcmp(s(14:15), 'CA')
            x = [x; str2double(s(33:38))];
            y = [y; str2double(s(41:46))];
            z = [z; str2double(s(49:54))];
        end
    end
end
fclose(fid);
```

Open the file.

```
fid = fopen('1bl18.dat', 'r');
x=[];y=[];z=[]; ←
while ~feof(fid)
    s = fgetl(fid);
    if strcmp(s(1:4), 'ATOM')
        if strcmp(s(14:15), 'CA')
            x = [x; str2double(s(33:38))];
            y = [y; str2double(s(41:46))];
            z = [z; str2double(s(49:54))];
        end
    end
end
fclose(fid);
```

Initialize xyz arrays

```
fid = fopen('1bl8.dat', 'r');
x=[];y=[];z=[];
while ~feof(fid) ←
    s = fgetl(fid);
    if strcmp(s(1:4), 'ATOM')
        if strcmp(s(14:15), 'CA')
            x = [x; str2double(s(33:38))];
            y = [y; str2double(s(41:46))];
            z = [z; str2double(s(49:54))];
        end
    end
end
fclose(fid);
```

Iterate Until End of File

```
fid = fopen('1bl8.dat', 'r');
x=[];y=[];z=[];
while ~feof(fid)
    s = fgetl(fid); ←
    if strcmp(s(1:4), 'ATOM')
        if strcmp(s(14:15), 'CA')
            x = [x; str2double(s(33:38))];
            y = [y; str2double(s(41:46))];
            z = [z; str2double(s(49:54))];
        end
    end
end
fclose(fid);
```

Get the next line from
file.

```
fid = fopen('1bl8.dat', 'r');
x=[];y=[];z=[];
while ~feof(fid)
    s = fgetl(fid);
    if strcmp(s(1:4), 'ATOM') ←
        if strcmp(s(14:15), 'CA') ←
            x = [x; str2double(s(33:38))];
            y = [y; str2double(s(41:46))];
            z = [z; str2double(s(49:54))];
        end
    end
end
fclose(fid);
```

Make Sure It's a
Backbone Amino Acid

```
fid = fopen('1bl8.dat', 'r');
x=[];y=[];z=[];
while ~feof(fid)
    s = fgetl(fid);
    if strcmp(s(1:4), 'ATOM')
        if strcmp(s(14:15), 'CA')
            x = [x; str2double(s(33:38))]; ←
            y = [y; str2double(s(41:46))]; ←
            z = [z; str2double(s(49:54))]; ←
        end
    end
end
fclose(fid);
```

Update the x, y, z
arrays