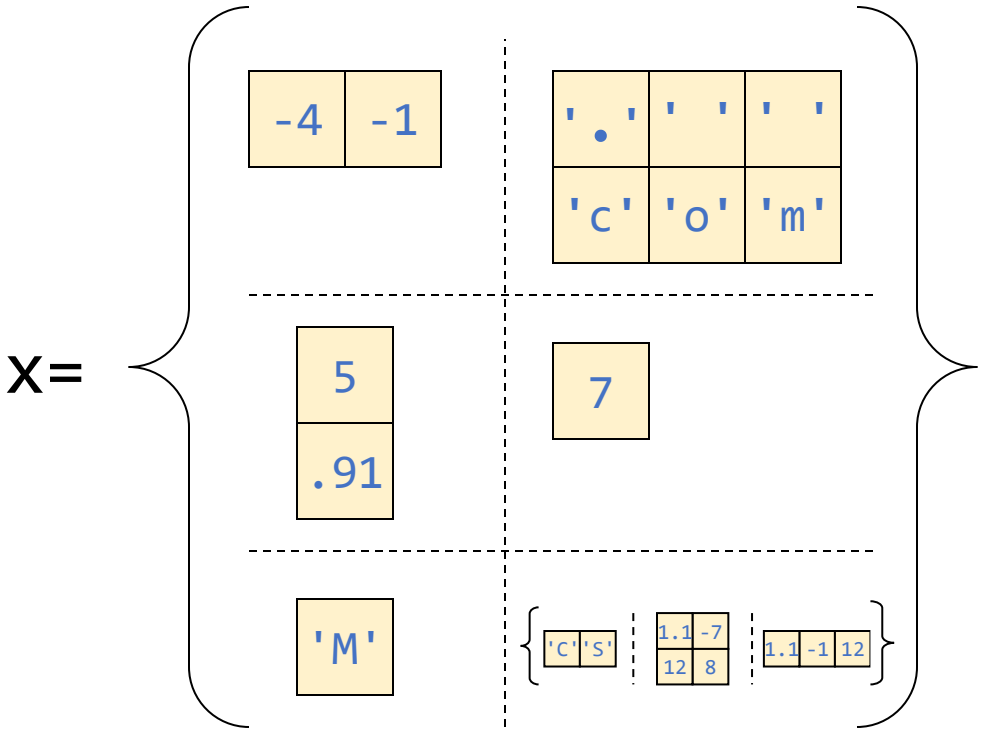
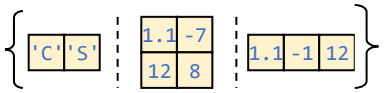
- Previous Lecture:
  - Review Linear Search
  - Cell arrays
- Today's Lecture:
  - File input/output
  - Using built-in function `sort`
  - Motivating packaging
- Announcements:
  - Answer today's in-lecture quiz via Gradescope (due Sat, 11:15am)
    - See Canvas for submission instructions
  - Test 2A will be released Tue
    - 50 minutes in 48 hr window
    - Matrices, images, char arrays, vectorized code
    - Review Sun
  - Tutoring available during consulting hours (sign up on Canvas)
    - Next week: no consulting, Piazza during test window (Tue/Wed)

Review: cell arrays



- `x{3,1}` → `'M'`
- `x{1,1}` → `[-4 -1]`
- `x{1,1}(2)` → `-1`
- `x{3,2}` → 
- `X{3,2}{1}` → `'CS'`
- `X{3,2}{1}(2)` → `'S'`

Review question

Given the cell array:

```
x= { 'A', [3, 1, 4], uint8(zeros(6,4)) }
```

Which expression changes the `1` in `x` to a `5`?

A
```
x(2,2)= 5
```

C
```
x{2}(2)= 5
```

B
```
y= x{2};
y(2)= 5
```

D
```
x(2)= [3, 5, 4]
```

gradescope

A detailed sort-a-file example

File **`statePop.txt`** contains state population data sorted alphabetically by state. Create a new file

`statePopSm2Lg.txt`

that is structured the same as **`statePop.txt`** except that *the states are ordered from smallest to largest according to population.*

`statePop.txt`

```
Alabama          4557808
Alaska            663661
Arizona          5939292
Arkansas         2779154
California      36132147
Colorado         4665177
   :                :
   :                :
```

- Need the pop as *numbers* for sorting.
- Can't just sort the pop— have to maintain association with the state names.

First, read the file and store each line in a cell of a cell array

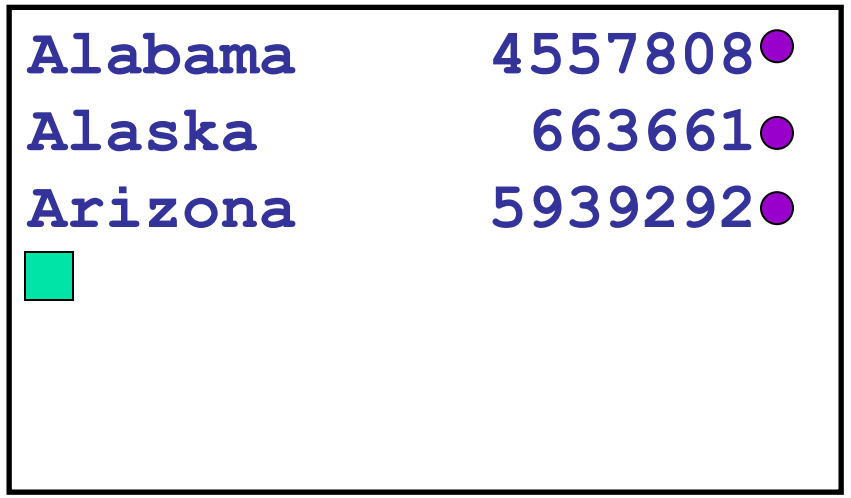
```
C = file2cellArray('StatePop.txt');
```

statePop.txt

```
Alabama          4557808
Alaska            663661
Arizona          5939292
Arkansas         2779154
California      36132147
Colorado         4665177
   :                :
   :                :
```

```
C= { 'Alabama          4557808';
     'Alaska            663661';
     …}
```

End-of-line and end-of-file



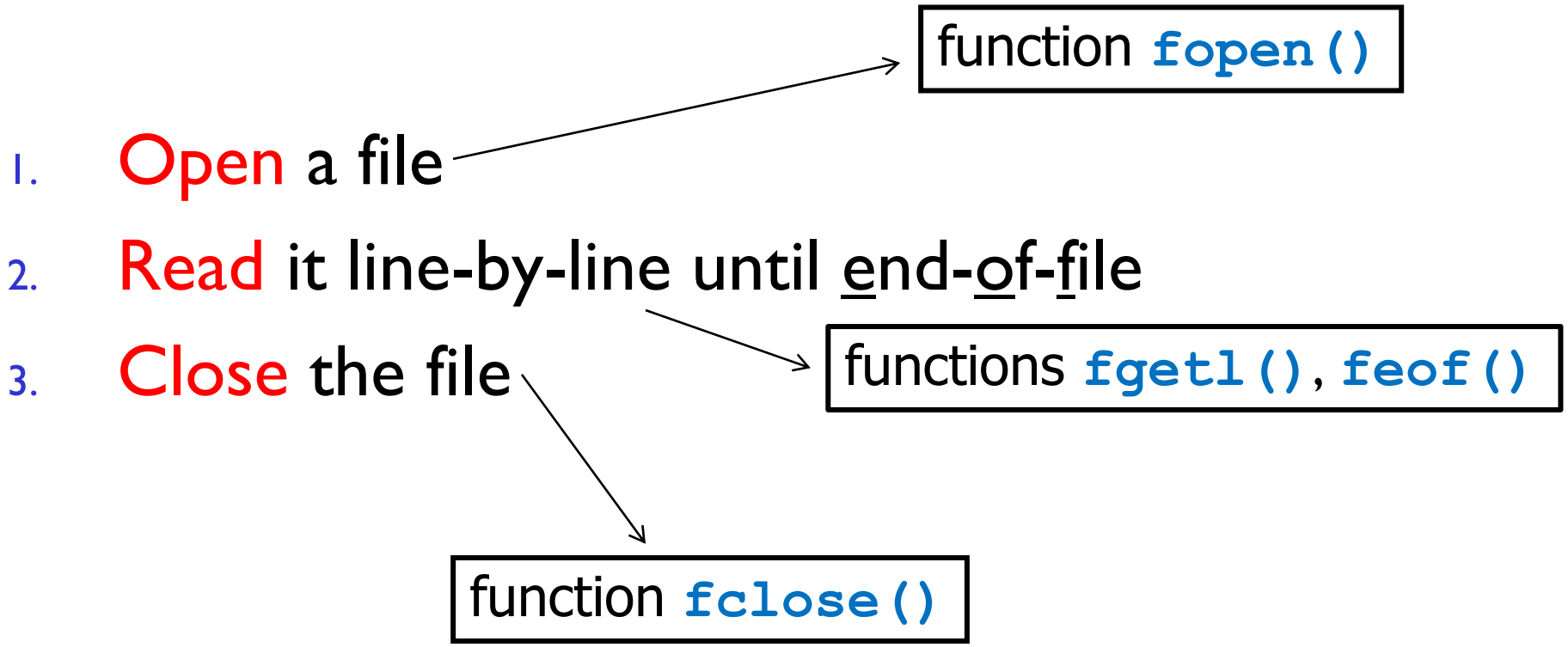
stateData.txt

- Line feed character ('\n') marks the end of a line

- Computer knows how many characters are in file, and therefore where it ends.

  eof stands for end of file

Read data from a file



Closing a file is like the `end` keyword – need to tell MATLAB when you're done

1 & 3: Open (and close) file

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

An opened 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 **r**eading

```
fclose(fid);
```

; because file commands return status codes

2: Read each line and store it in cell array

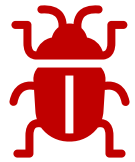
```
fid = fopen('statePop.txt', 'r');

k= 0;
while ~feof(fid)
    k= k+1;
    Z{k}= fgetl(fid);
end

fclose(fid);
```

False until end-of-file is reached

Get the next line.
(Each call gets one line; you cannot go to a specific line.)



Doesn't work for empty files

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

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

C

```
{ 'Alab   4558000'
  'Alas    664000'
    :
  'Cali  36132000'



  'Verm    623000'
     .
     .
  'Wyom    509000' }
```

cell array
of strings
in alpha. order

C

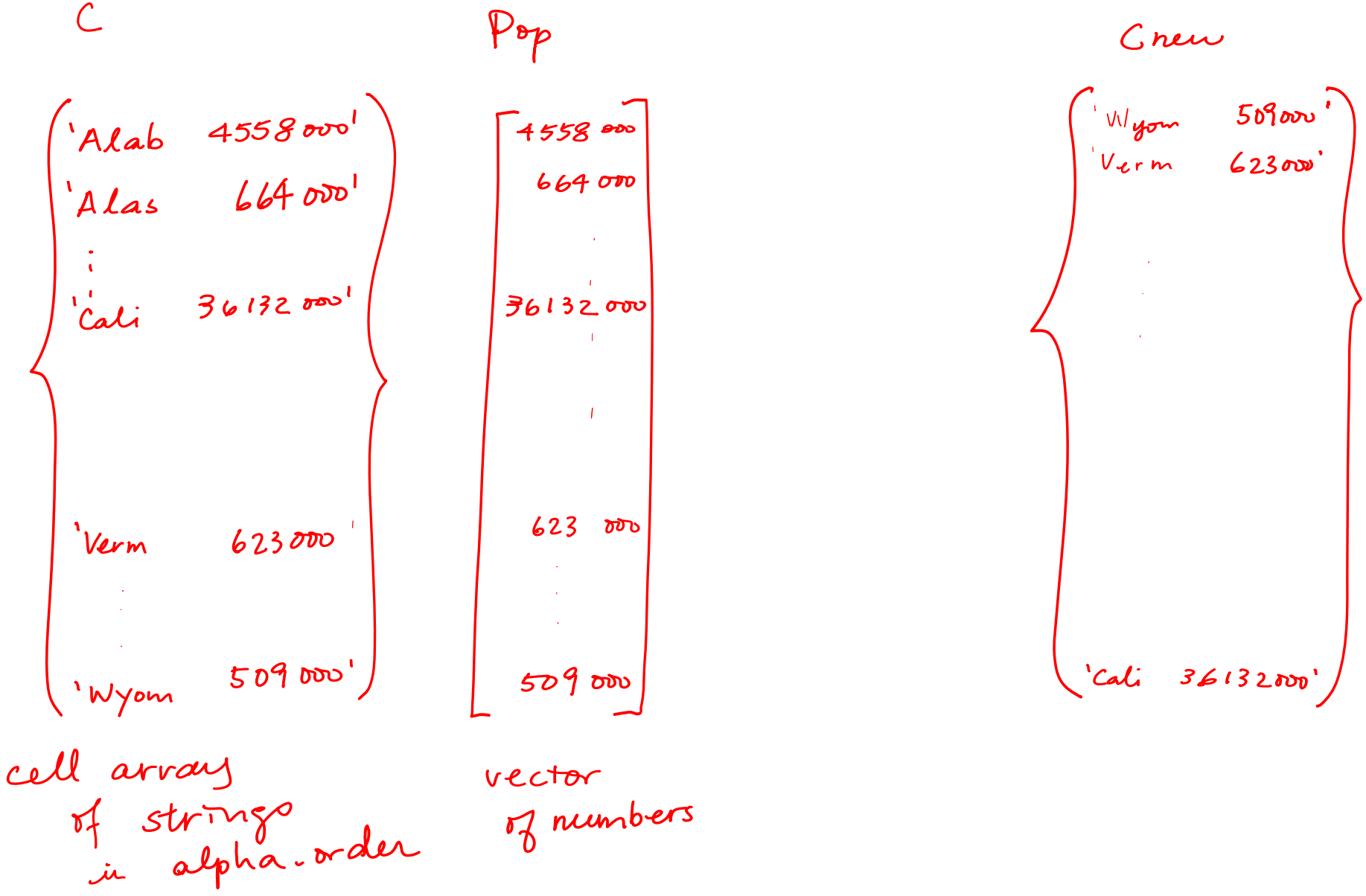
{ 'Alab 4558000'
'Alas 664000'
:
'Cali 36132000'

'Verm 623000'
.
.
'Wyom 509000' }

cell array
of strings
in alpha. order

Crew

{ 'Wyom 509000'
'Verm 623000'
.
.
.
'Cali 36132000' }


C
Pop
Crew
'Alab 4558000'
'Alas 664000'
'Cali 36132000'
'Verm 623000'
'Wyom 509000'
4558000
664000
36132000
623000
509000
'Wyom 509000'
'Verm 623000'
'Cali 36132000'
cell array
of strings
in alpha. order
vector
of numbers

Extracting population

- Two steps:
  1. Extract substring containing pop (and not name)
  2. Convert string (char vector) into number (scalar)

```
New York          19254630
North Carolina     8683242
123456789012345678901234
          1           2
```

Slicing question

Assume 'statePop.txt' is read into C using `file2CellArray()`. Which of these expressions evaluates to 'zona'?

statePop.txt

```
Alabama          4557808
Alaska            663661
Arizona          5939292
Arkansas         2779154
California      36132147
Colorado         4665177
   :                   :
   :                   :
```

A `C{3,4:7}`

C `C{3}(4:7)`

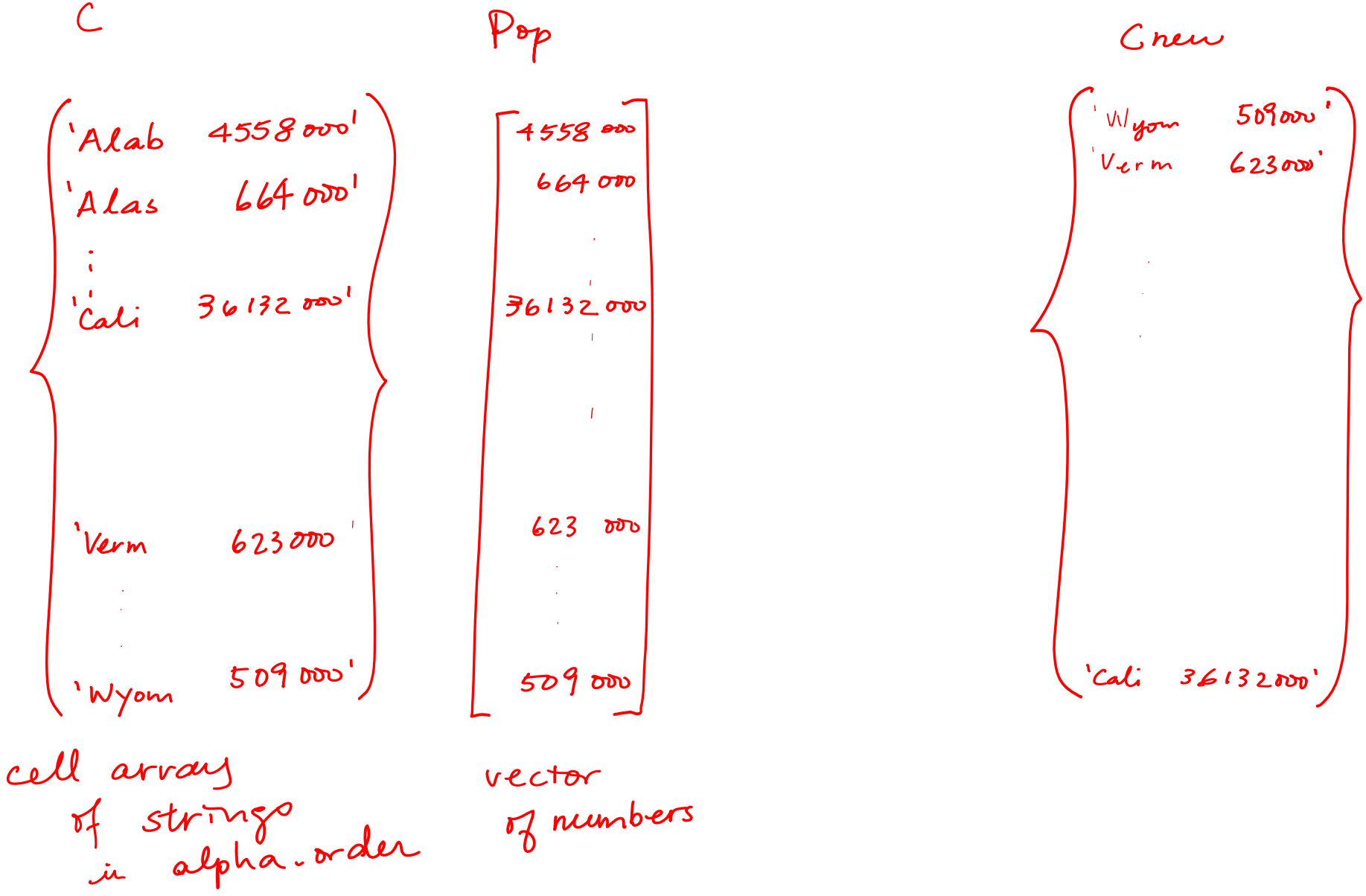
B `C(3,4:7)`

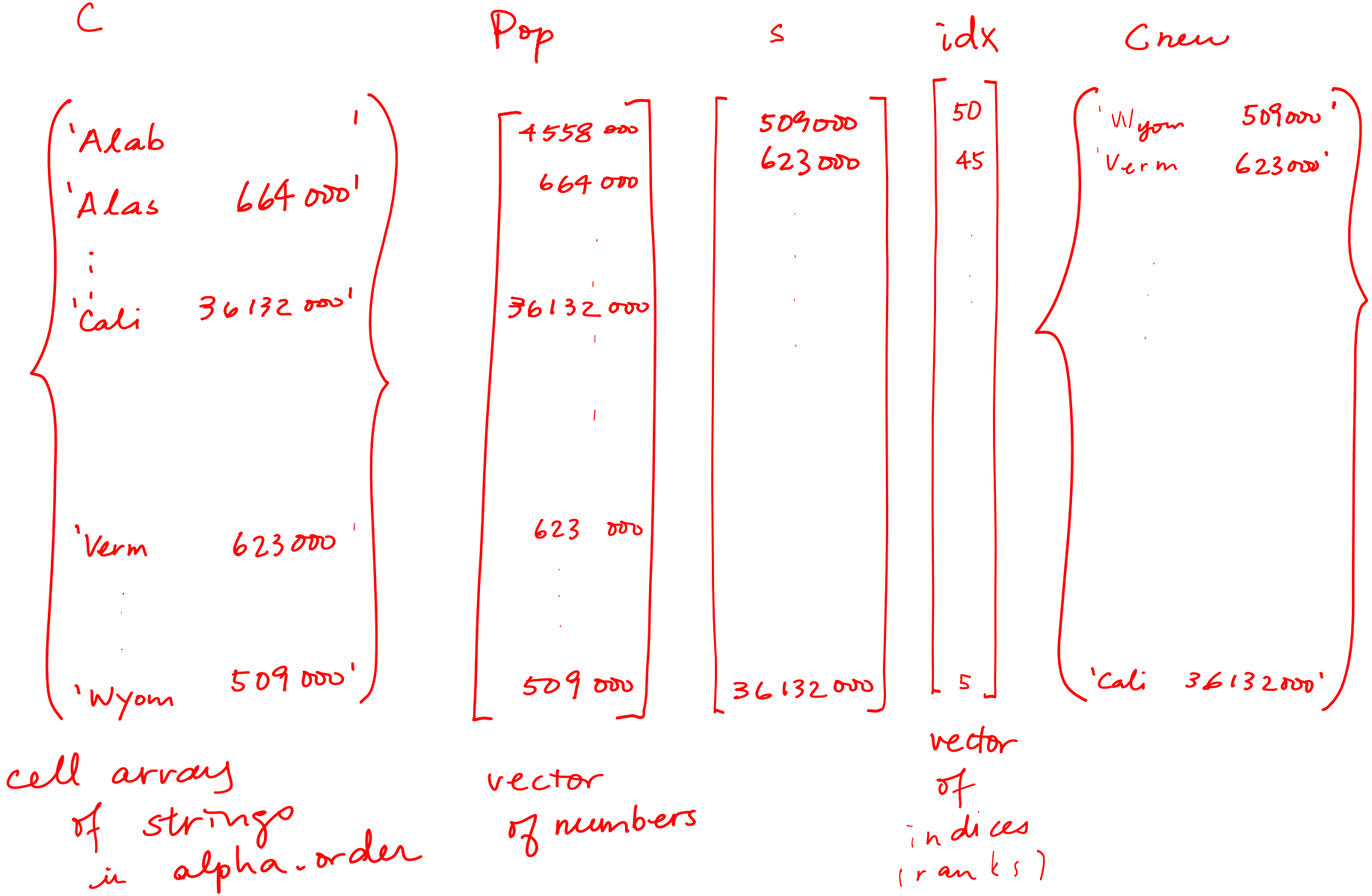
D `C(4:7,3)`

Next, get the populations into a numeric vector

```
C = file2cellArray('StatePop.txt');
n = length(C);
pop = zeros(n,1);
for i=1:n
   S = C{i};
   pop(i) = str2double(S(16:24));
end
```

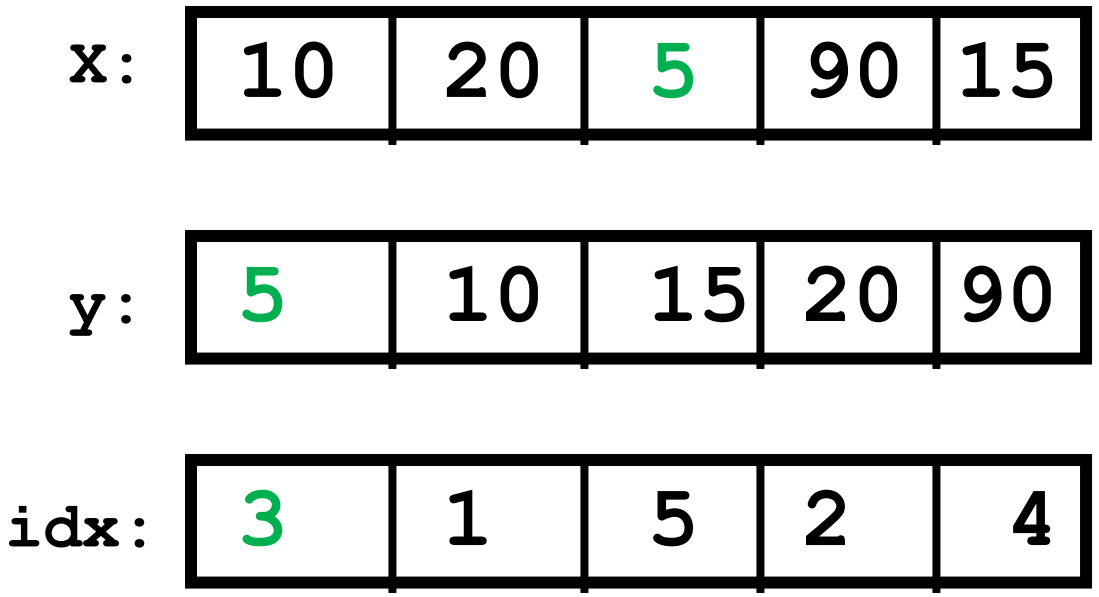
Converts a *string* representing a numeric value (digits, decimal point, spaces) to the numeric value → scalar of type *double*. E.g., `x=str2double(' -3.24 ')` assigns to variable `x` the numeric value -3.2400…


C
Pop
Crew
'Alab 4558000'
'Alas 664000'
'Cali 36132000'
'Verm 623000'
'Wyom 509000'
4558000
664000
36132000
623000
509000
'Wyom 509000'
'Verm 623000'
'Cali 36132000'
cell array
of strings
in alpha. order
vector
of numbers


C
Pop
s
idx
Crew
'Alab
'Alas 664 000'
'Cali 36132 000'
'Verm 623000'
'Wyom 509 000'
4558 000
664 000
36132 000
623 000
509 000
509000
623000
36132000
50
45
5
'Wyom 509000'
'Verm 623000'
'Cali 36132000'
cell array of strings in alpha. order
vector of numbers
vector of indices (ranks)

Built-In function `sort`

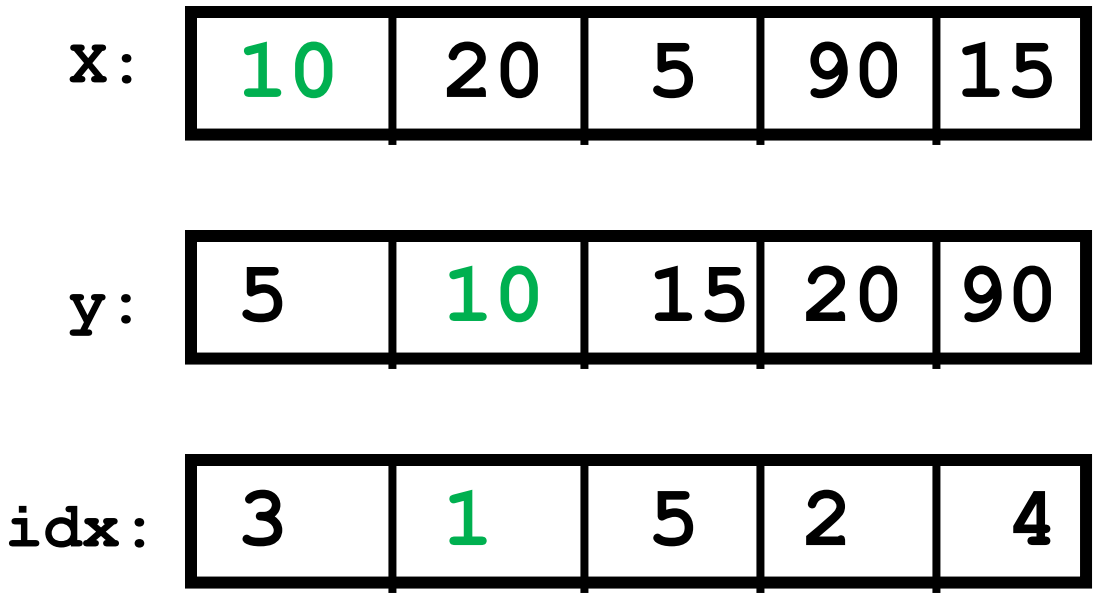
Syntax: `[y,idx] = sort(x)`




```
y(1) = x(3) = x(idx(1))
```

Built-In function `sort`

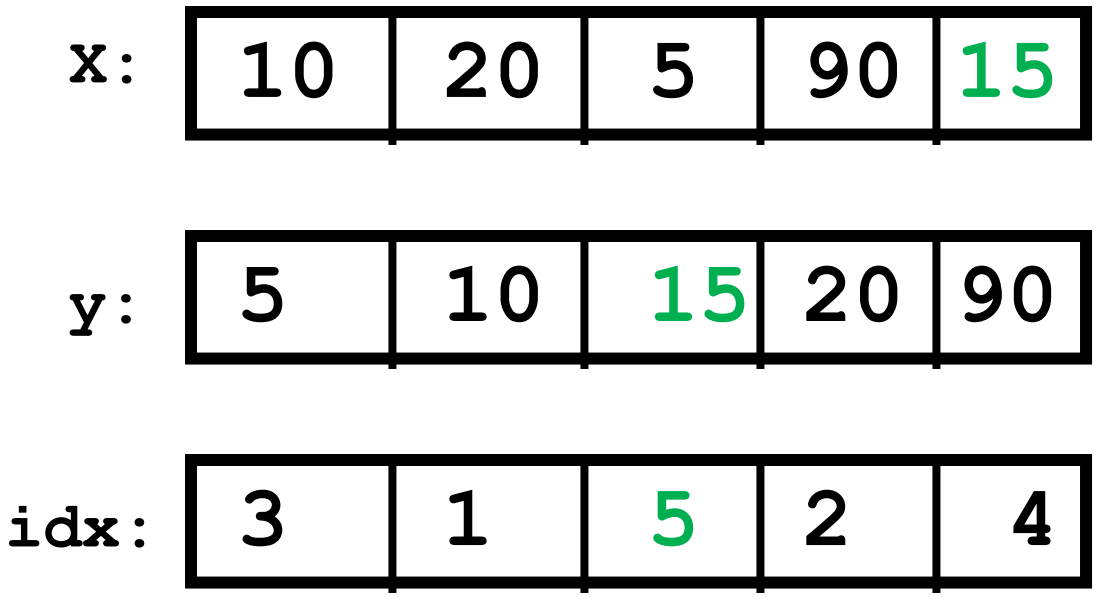
Syntax: `[y,idx] = sort(x)`




```
y(2) = x(1) = x(idx(2))
```

Built-In function `sort`

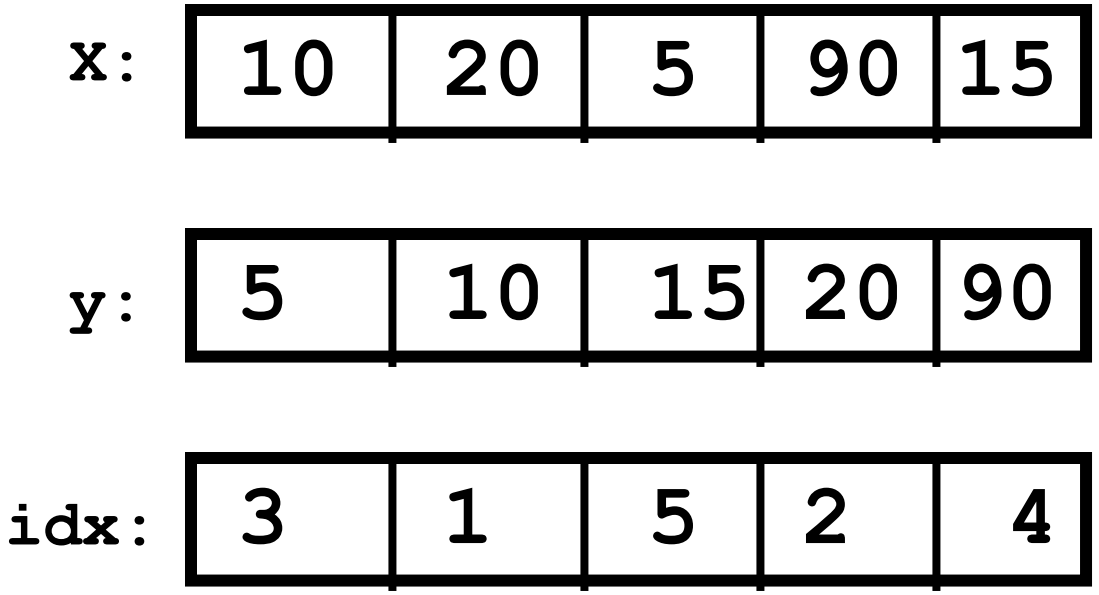
Syntax: `[y,idx] = sort(x)`



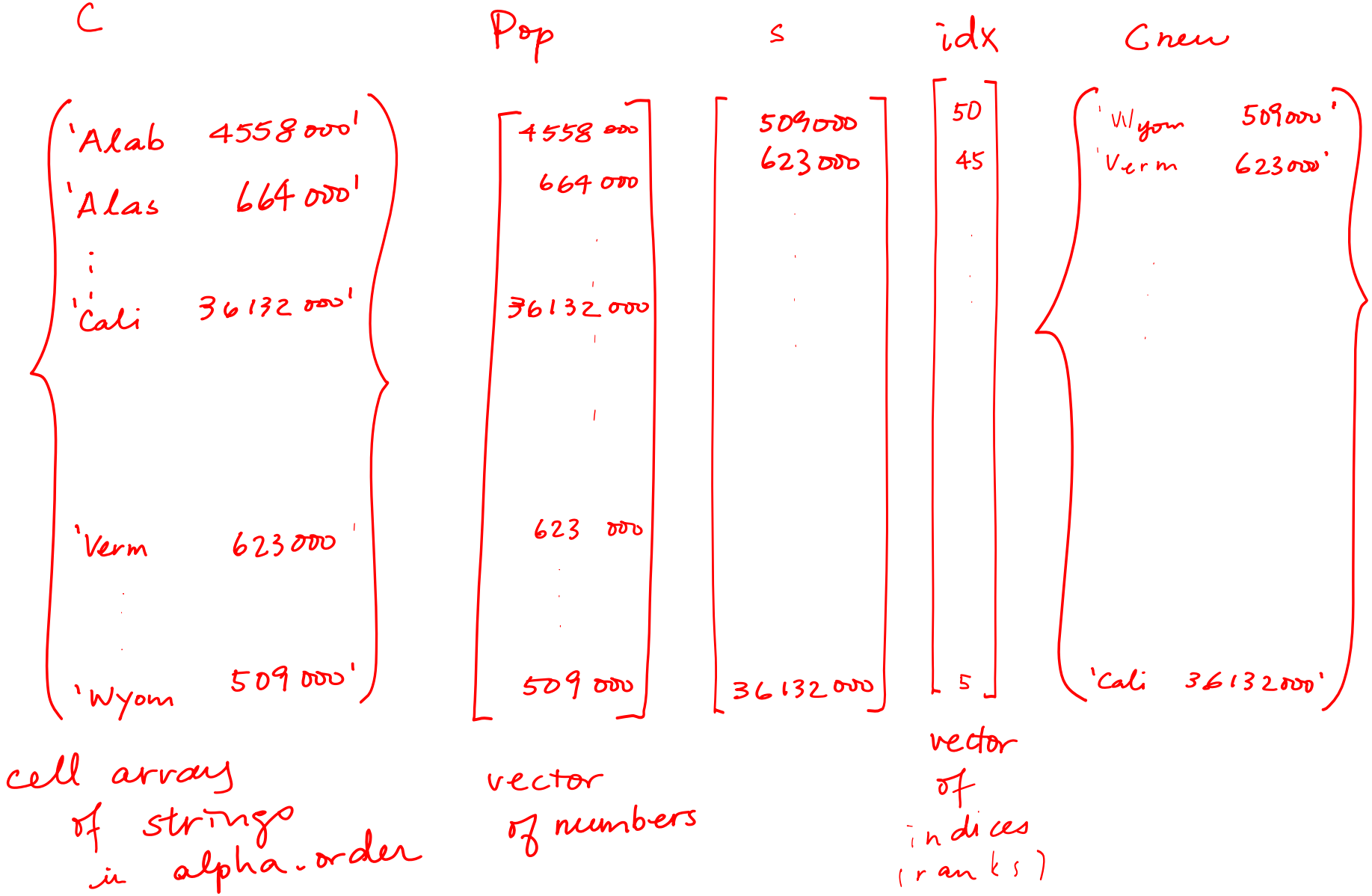
`y(3) = x(5) = x(idx(3))`

Built-In function `sort`

Syntax: `[y,idx] = sort(x)`



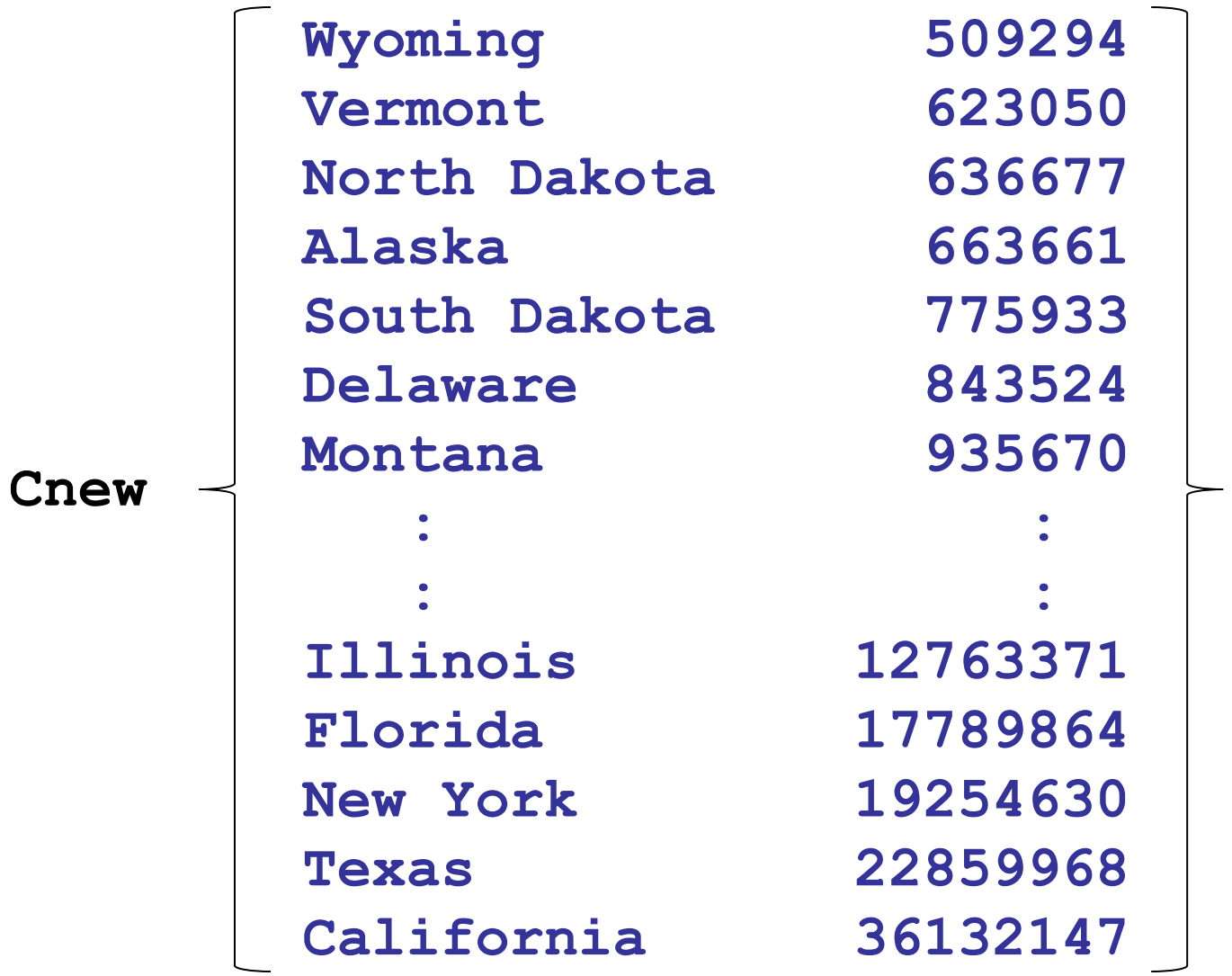

```
y(k) = x(idx(k))
```


C
Pop
s
idx
Crew
'Alab 4558000'
'Alas 664000'
'Cali 36132000'
'Verm 623000'
'Wyom 509000'
4558000
664000
36132000
623000
509000
509000
623000
36132000
50
45
5
'Wyom 509000'
'Verm 623000'
'Cali 36132000'
cell array of strings in alpha. order
vector of numbers
vector of indices (ranks)

Sort from little to big

```
% C is cell array read from statePop.txt
% pop is vector of state pop (numbers)
[s,idx] = sort(pop);
Cnew = cell(n,1);
for i=1:length(Cnew)
    ithSmallest = idx(i);
    Cnew{i} = C{ithSmallest};
end
```

```
Cnew{i} = C{idx(i)};
```


Cnew
Wyoming 509294
Vermont 623050
North Dakota 636677
Alaska 663661
South Dakota 775933
Delaware 843524
Montana 935670
: :
: :
Illinois 12763371
Florida 17789864
New York 19254630
Texas 22859968
California 36132147

Sorting question

Assume you have `C`, `pop`, `s`, and `idx` as defined previously in this lecture. Write a code snippet that prints the names of the states whose populations are between the 20th and 40th percentile.

Statistics review: 1/5 of states will have smaller populations than the ones you print, and 3/5 of states will have larger populations.

Save results

```
% C is cell array read from statePop.txt
% pop is vector of state pop (numbers)
[s,idx] = sort(pop);
Cnew = cell(n,1);
for i=1:length(Cnew)
    ithSmallest = idx(i);
    Cnew{i} = C{ithSmallest};
end
```

```
cellArray2file(Cnew,'statePopSm2Lg.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

1. Open a file (don't forget to later close the file)

```
fid = fopen('popSm2Lg.txt', 'w');
```

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

Built-in function to open a file

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

'**w**' indicates that the file is to be opened for **w**riting

Use '**a**' for **a**ppending

```
fclose(fid);
```

2. Write (print) to the file

```
fid = fopen('popSm2Lg.txt', 'w');

for i=1:length(Cnew)
    fprintf(fid, '%s\n', Cnew{i});
end

fclose(fid);
```

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* `Cnew`

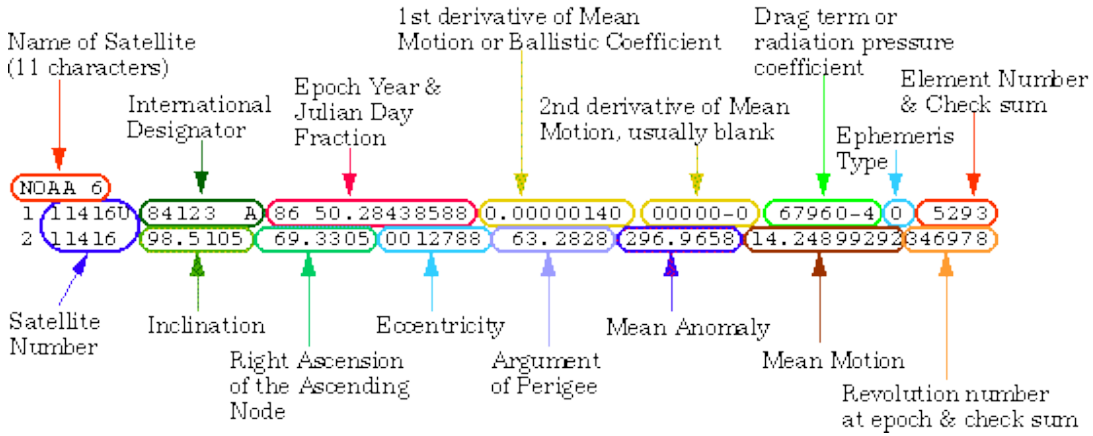
```
function cellArray2file(CA, fname)
% CA is a cell array of strings.
% Create a file with the name
% specified by the string fname.
% The i-th line in the file is CA{i}

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

Storing only a selected (small) section of data from a big file

- The previous example reads the whole file and stores all the text
- If you're interested in only a small part of the data, storing everything is an overkill
- Read "issYear.m" posted on the website to learn how to store only the data that meet certain criteria

Example: NORAD two-line elements




```
ISS (ZARYA)
1 25544U 98067A   19280.43177083  .00000288  00000-0  13040-4 0  9993
2 25544  51.6437 164.6585 0007556 123.5429 237.5675 15.50172544192676
⋮
STARLINK-74
1 44293U 19029BL  19280.46307273  .00000774  00000-0  72445-4 0  9999
2 44293  53.0058 280.3384 0001435  93.2755 266.8397 15.05496611 21751
STARLINK-53
1 44294U 19029BM  19279.64653505  .00000628  00000-0  62400-4 0  9998
2 44294  52.9988 283.1290 0000873  99.6752 260.4335 15.05478127 19808
COSMOS 2534 [GLONASS-M]
1 44299U 19030A   19279.63973935  .00000042  00000-0  00000+0 0  9999
2 44299  64.7328 275.7191 0015277 282.8642  34.0841  2.13101948  2816
```

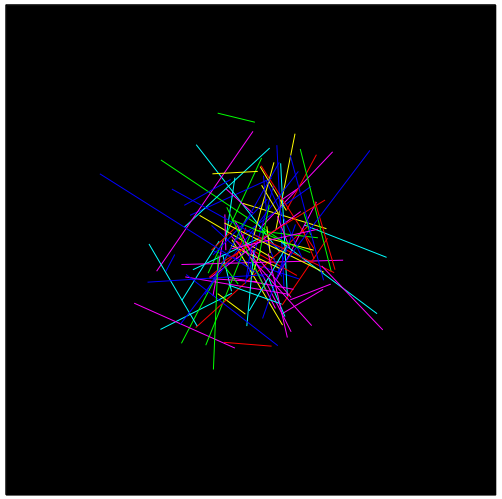
Website example: satellite launch year

1. Read line (satellite name)
2. While name is not ISS
    1. Read 2 lines (skip)
    2. Read line (satellite name)
3. Read line (record 1)
4. Extract characters 10 & 11
5. Convert to number, interpret as year

```
SCD 2
1 25504U 98060A   19288.18395014  .00000230  00000-0  13957-4 0  9992
2 25504  24.9967 317.5526 0017113 331.0386 103.7958 14.44077629107938
ISS (ZARYA)
1 25544U 98067A   19280.43177083  .00000288  00000-0  13040-4 0  9993
2 25544  51.6437 164.6585 0007556 123.5429 237.5675 15.50172544192676
⋮
STARLINK-53
1 44294U 19029BM  19279.64653505  .00000628  00000-0  62400-4 0  9998
2 44294  52.9988 283.1290 0000873  99.6752 260.4335 15.05478127 19808
COSMOS 2534 [GLONASS-M]
1 44299U 19030A   19279.63973935  .00000042  00000-0  00000+0 0  9999
2 44299  64.7328 275.7191 0015277 282.8642  34.0841  2.13101948  2816
```

Data are often related

- A point in the plane has an x coordinate and a y coordinate.
- If a program manipulates lots of points, there will be lots of x's and y's.
- Anticipate clutter. Is there a way to "package" the two coordinate values?



Packaging affects thinking

Our Reasoning Level:

P and Q are points.
Compute the midpoint M of the connecting line segment.

Behind the scenes we do this:

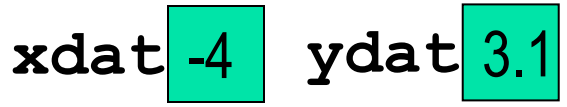
$$M_x = (P_x + Q_x)/2$$
$$M_y = (P_y + Q_y)/2$$

We've seen this before: functions are used to "package" calculations.

This packaging (a type of abstraction) elevates the level of our reasoning and is critical for problem solving.

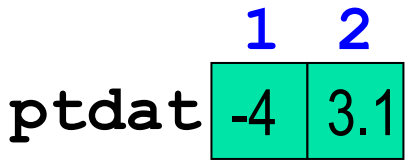
Options for storing a point (-4, 3.1)

- **Simple scalars**



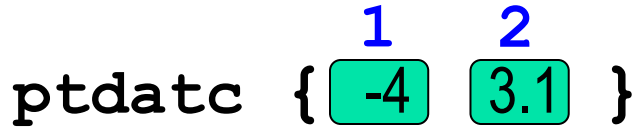
Ungrouped data

- **Simple vector**

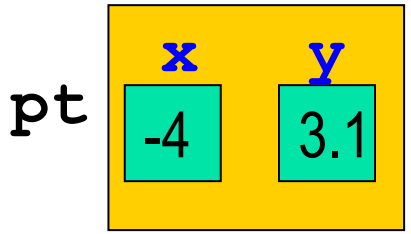


Related data grouped into an array. X-coord implicitly labelled 1; y-coord implicitly labelled 2

- **Cell array**



- **Object**



Related data grouped according to a class definition. Explicit, clear labelling is possible via property names