- Previous Lecture:
  - Structs and struct arrays
- Today's Lecture:
  - More on topics from previous two lectures:
    - Cell arrays
    - File I/O
    - Structs
  - Built-in function sort
- Announcements:
  - Project 5 due Thurs April 16th at 11pm
  - Please give us feedback on consulting (at ACCEL) if you like

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

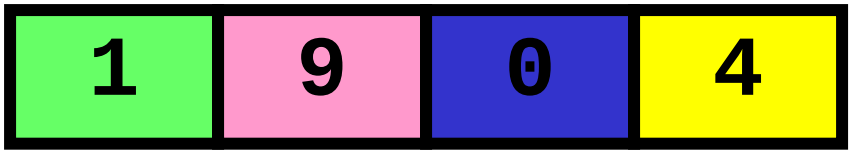
```
C{1} = 'I'
C{2} = 'II'
C{3} = 'III'
   :
C{2007} = 'MMVII'
   :
C{3999} = 'MMMXMXCIX'
```

Example

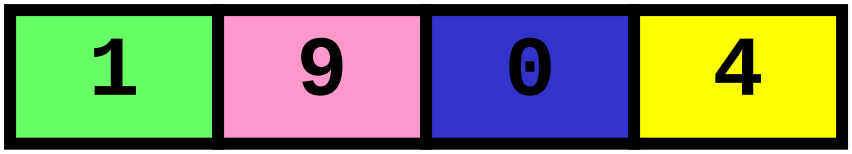
1904 = 1*1000 + 9*100 + 0*10 + 4*1

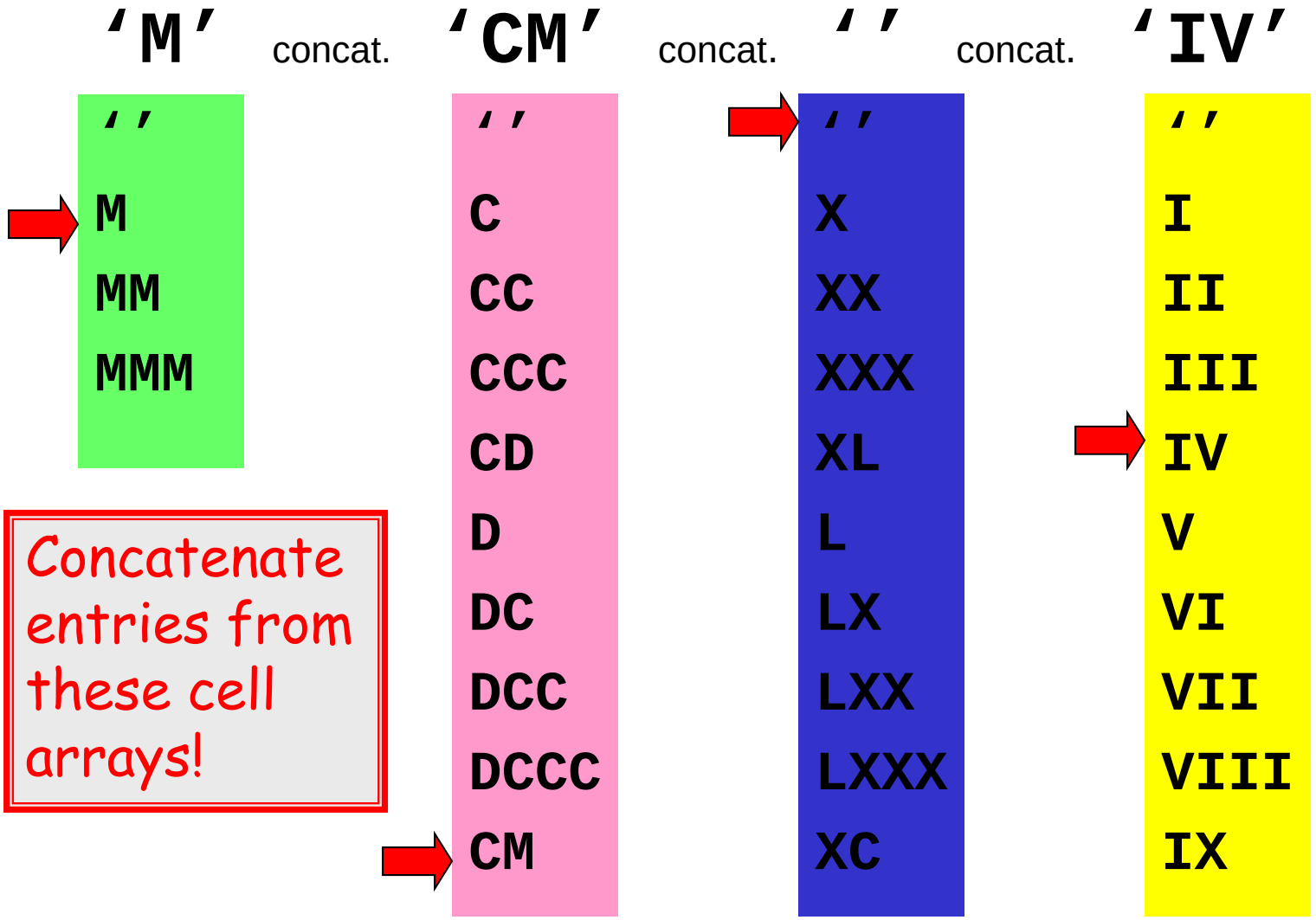
= M CM IV

= MCMIV



MCMIV


1
9
0
4


'M'
concat.
'CM'
concat.
''
concat.
'IV'
''
M
MM
MMM
''
C
CC
CCC
CD
D
DC
DCC
DCCC
CM
''
X
XX
XXX
XL
L
LX
LXX
LXXX
XC
''
I
II
III
IV
V
VI
VII
VIII
IX
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
```

We want all the Roman Numerals from 1 to 3999. We have the functions Ones2R, Tens2R, Hund2R, Thou2R.

The code to generate all the Roman Numerals will include loops—nested loops. How many are needed?

A: 2 B: 4 C: 6 D: 8

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
```

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
```

Four strings concatenated together

The n^{th} component of cell array C

The reverse conversion problem

Given a Roman Numeral, compute its value.

Assume cell array **`C(3999,1)`** available where:

```
C{1} = 'I'
C{2} = 'II'
   :
C{3999} = 'MMMCMXCIX'
```

```
function k = RN2Int(r)
% r is a string.  If r represents a Roman
% numeral then k is its value.

C= RomanNum();  % C{k} is Roman numeral for k,
                % 1<=k<=3999
len= length(C);

k= 1;
while k<=len && ~strcmp(r,C{k})
    k= k+1;
end
if k>len
    fprintf('%s is not a Roman Numeral\n', r)
    k= [];
    % else k is the correct value
end
```

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!

A detailed sort-a-file example

Suppose each line in the file

`statePop.txt`

is structured as follows:

Cols 1-14: State name

Cols 16-24: Population (millions)

The states appear in alphabetical order.

Alabama	4557808
Alaska	663661
Arizona	5939292
Arkansas	2779154
California	36132147
Colorado	4665177
:	:
:	:
Texas	22859968
Utah	2469585
Vermont	623050
Virginia	7567465
Washington	6287759
West Virginia	1816856
Wisconsin	5536201
Wyoming	509294

A detailed sort-a-file example

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.*

```
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');
```

C

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

Cnew

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

C

{ 'Alab 4558000'
'Alas 664000'
⋮
'Cali 36132000'
'Verm 623000'
⋮
'Wyom 509000' }

cell array
of strings
in alpha. order

Pop

[4558000
664000
⋮
36132000
⋮
623000
⋮
509000]

vector
of numbers

Crew

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

Next, get the populations into a numeric vector

```
C = file2cellArray('StatePop');
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 3.24

C

{ 'Alab 4558000'
'Alas 664000'
⋮
'Cali 36132000'
'Verm 623000'
⋮
'Wyom 509000' }

cell array
of strings
in alpha. order

Pop

[4558000
664000
⋮
36132000
⋮
623000
⋮
509000]

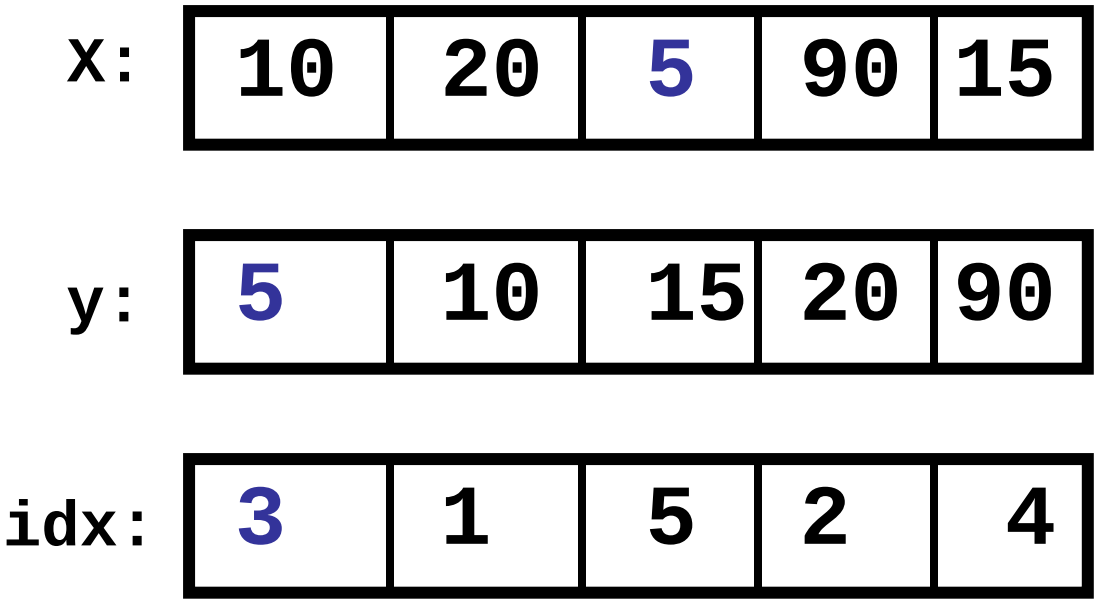
vector
of numbers

Crew

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

Built-In function `sort`

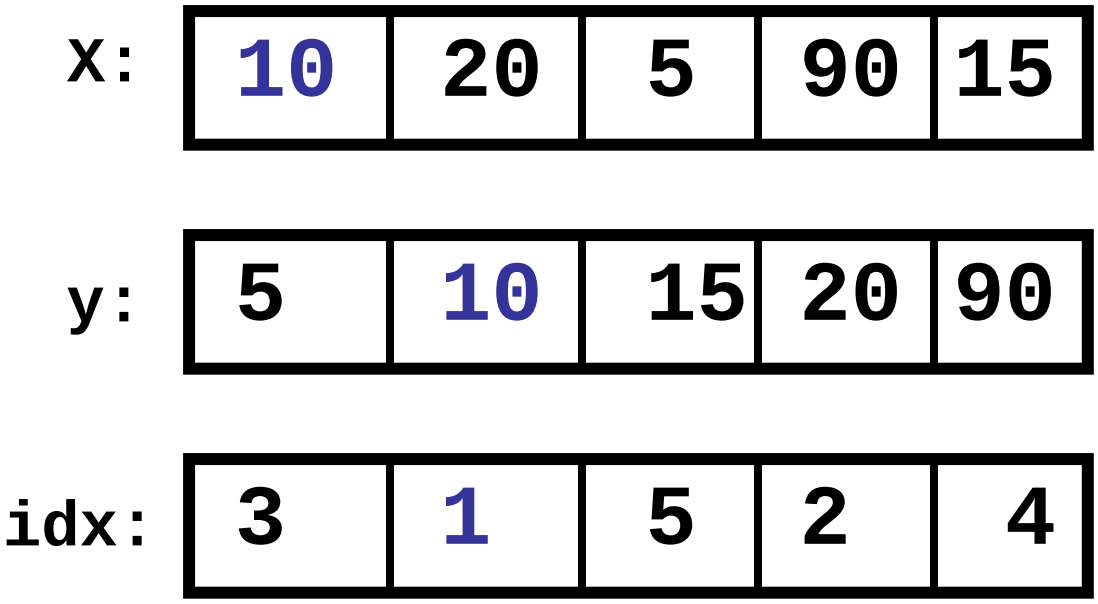
Syntax: `[y,idx] = sort(x)`




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

Built-In function `sort`

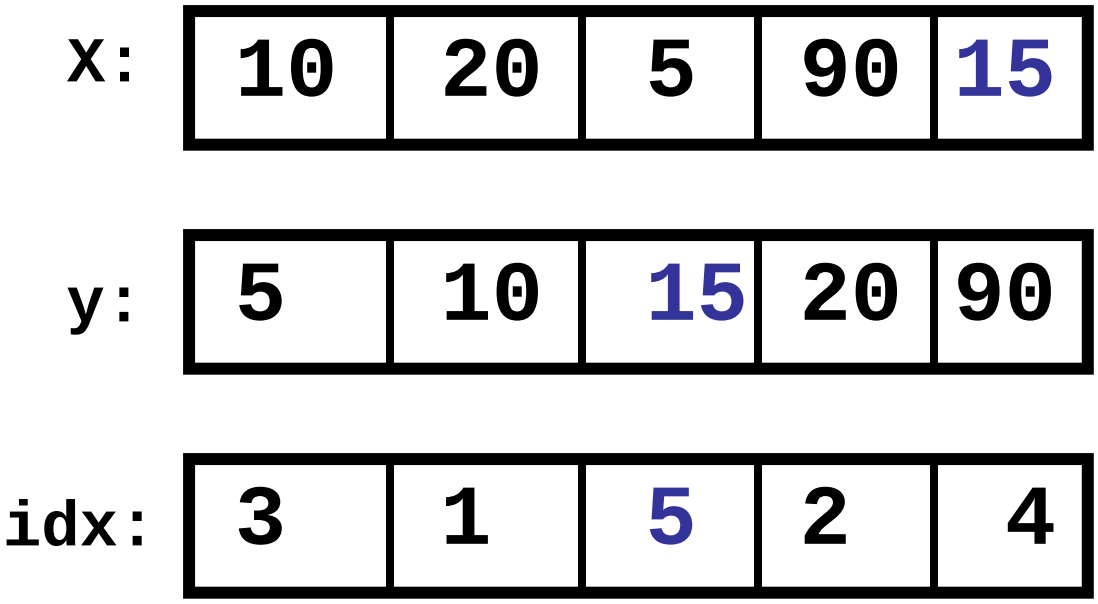
Syntax: `[y,idx] = sort(x)`




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

Built-In function `sort`

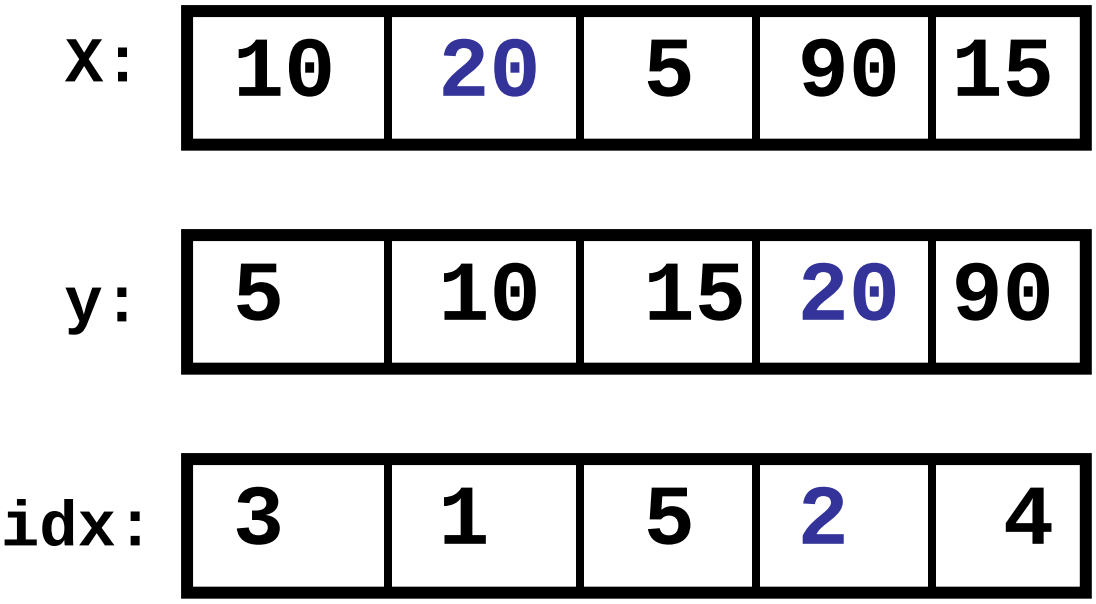
Syntax: `[y,idx] = sort(x)`



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

Built-In function `sort`

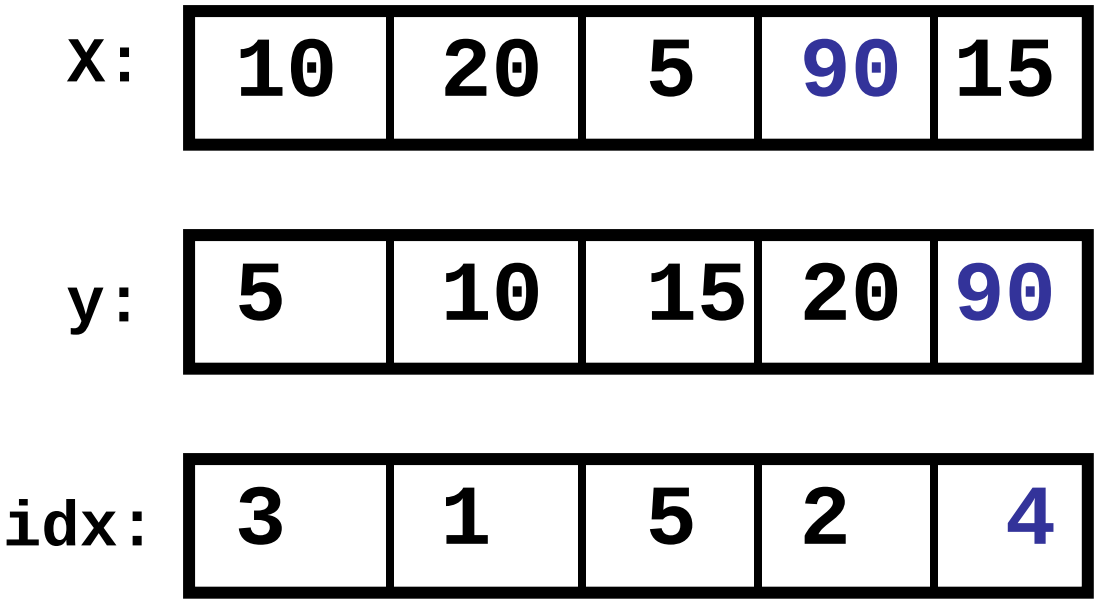
Syntax: `[y,idx] = sort(x)`




```
y(4) = x(2) = x(idx(4))
```

Built-In function `sort`

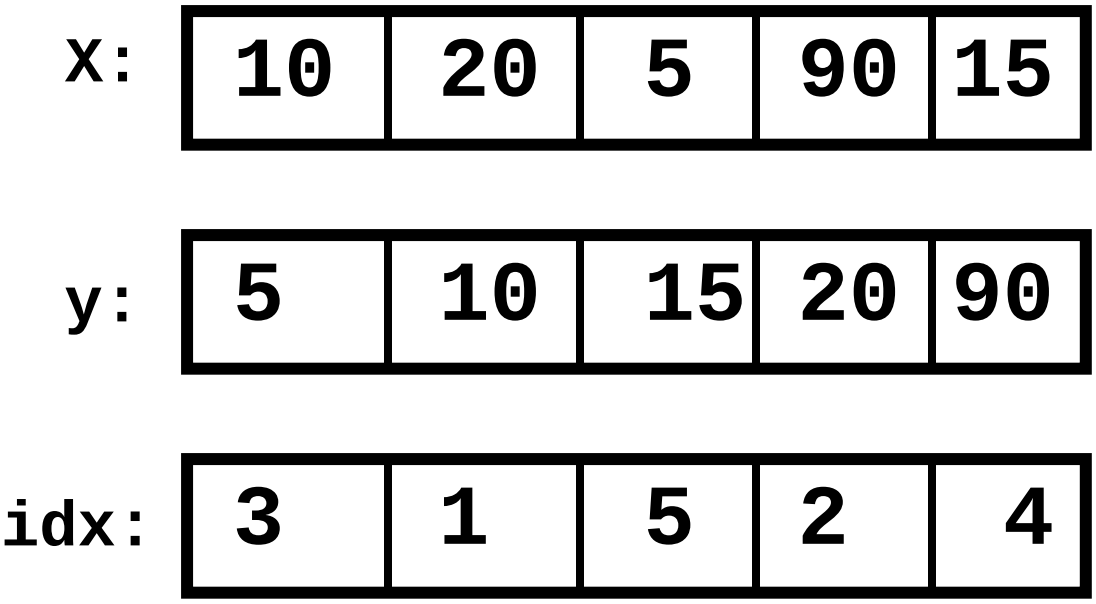
Syntax: `[y,idx] = sort(x)`



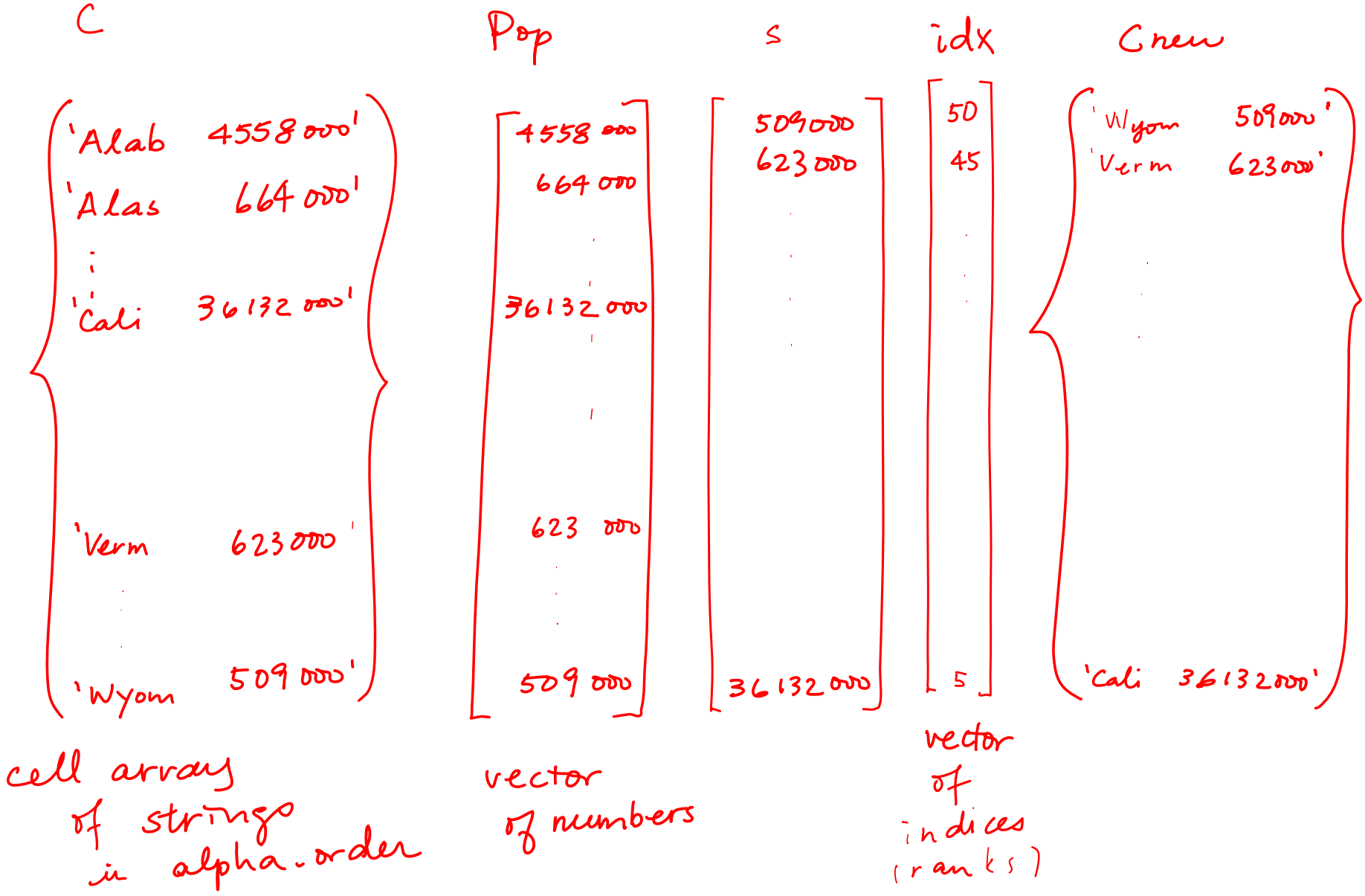
`y(5) = x(4) = x(idx(5))`

Built-In function `sort`

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




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


C
Pop
s
idx
Cnew
'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(C)
    ithSmallest = idx(i);
    Cnew{i} = C{ithSmallest};
end

cellArray2file(Cnew,'statePopSm2Lg')
```

```
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
```

Structures with array fields

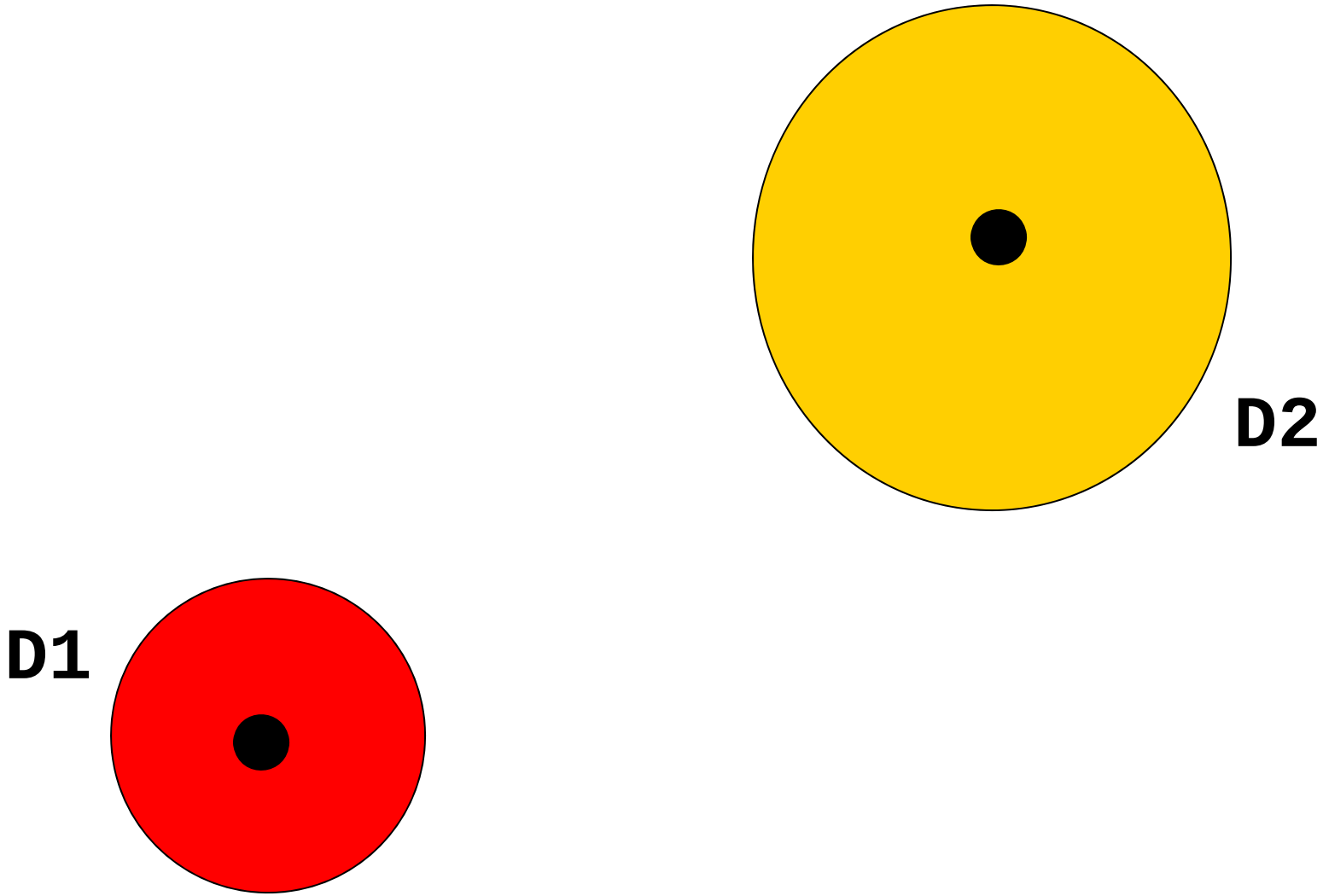
Let's develop a structure that can be used to represent a colored disk. It has four fields:

```
xc:  x-coordinate of center
yc:  y-coordinate of center
r:   radius
c:   rgb color vector
```

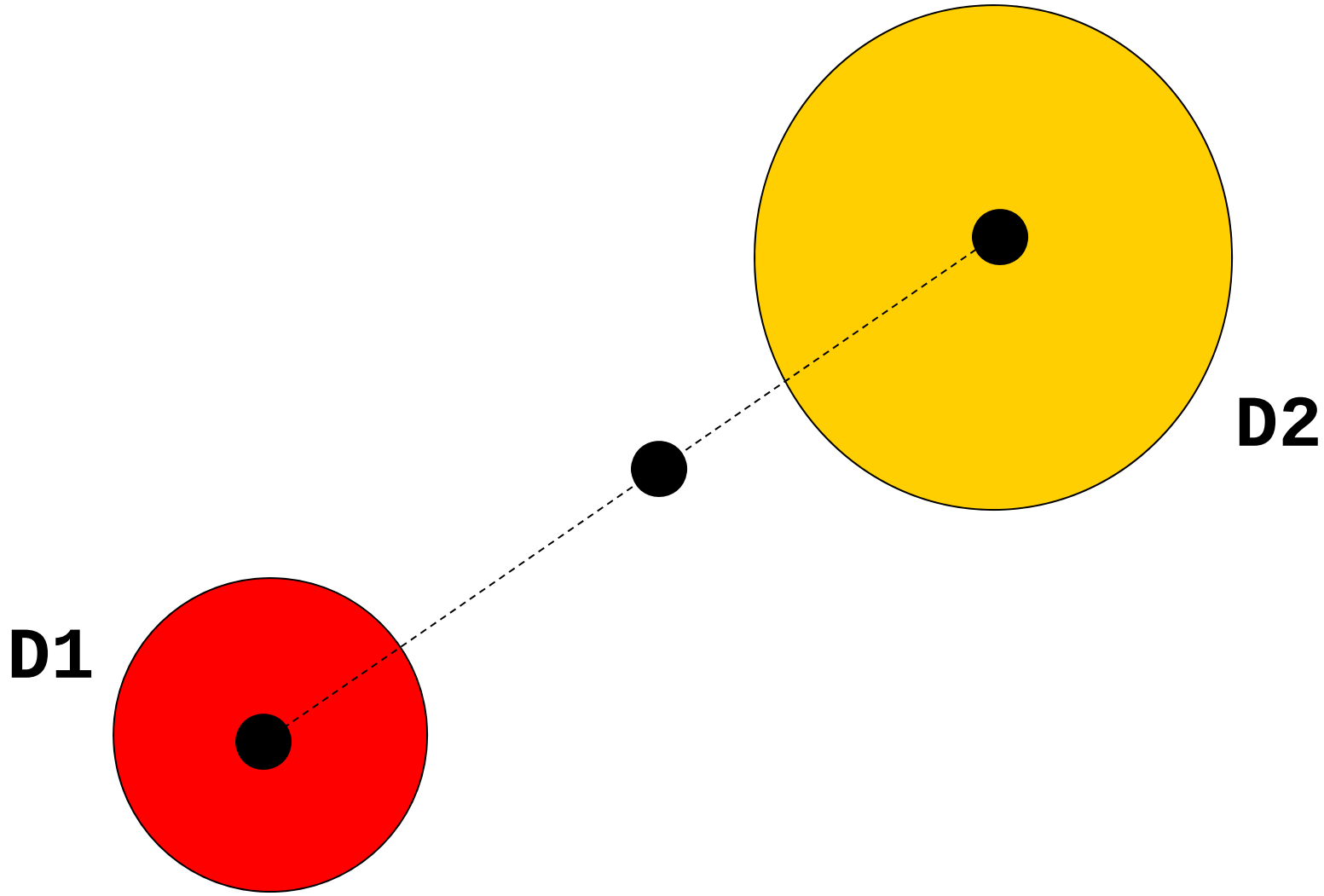
Examples:

```
D1 = struct('xc',1,'yc',2,'r',3,…
            'c',[1 0 1]);
D2 = struct('xc',4,'yc',0,'r',1,…
            'c',[.2 .5 .3]);
```

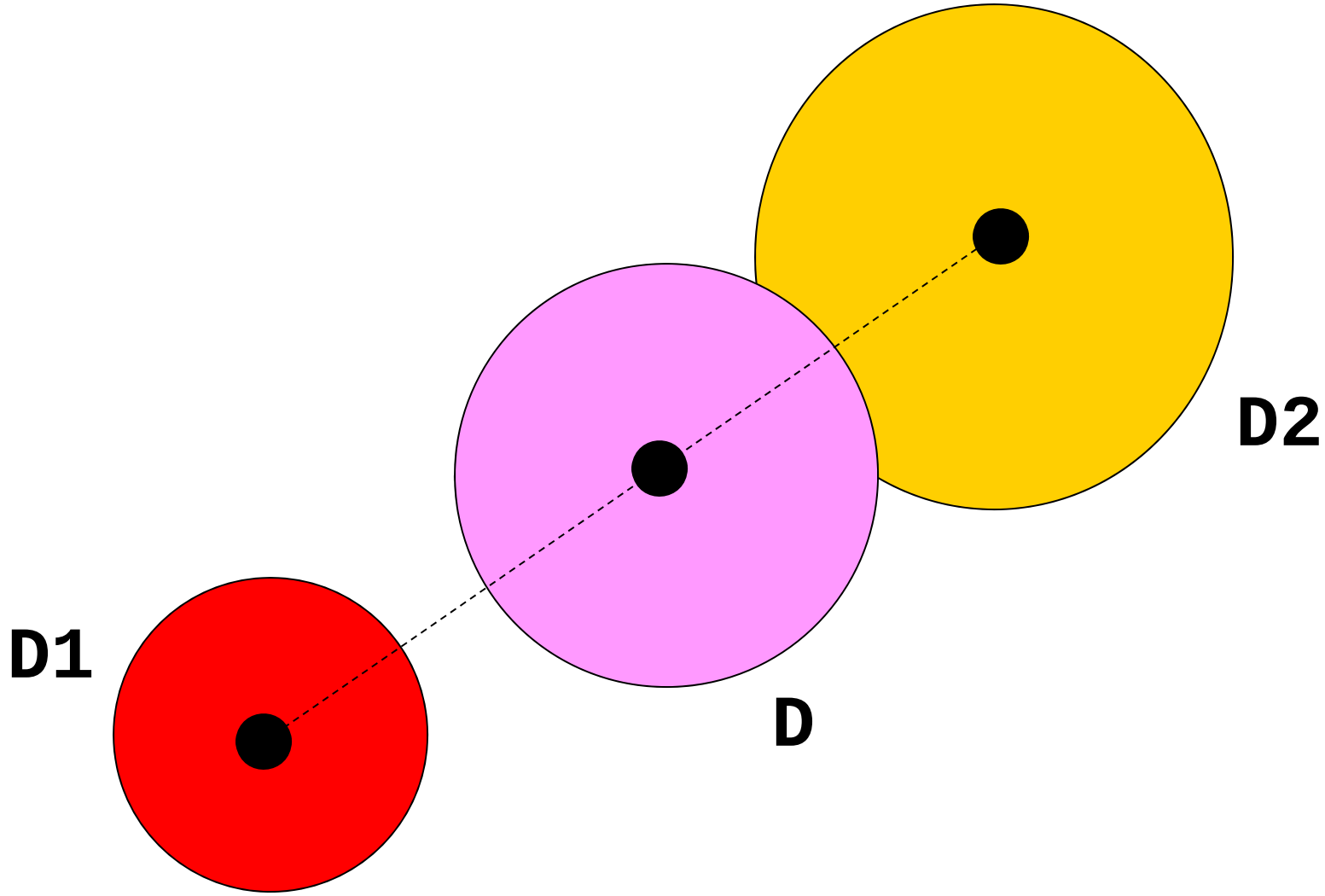
Example: Averaging two disks



Example: Averaging two disks



Example: Averaging two disks



Example: compute "average" of two disks

```
% D1 and D2 are disk structures.
% Average is:
r  = (D1.r  + D2.r) /2;
xc = (D1.xc + D2.xc)/2;
yc = (D1.yc + D2.yc)/2;
c  = (D1.c  + D2.c) /2;

% The average is also a disk
D = struct('xc',xc,'yc'yc,'r',r,'c',c)
```

How do you assign to **g** the green-color component of disk **D**?

```
D= struct('xc',3.5, 'yc',2, ...
          'r',1.0, 'c',[.4 .1 .5])
```

A: `g = D.g;`

B: `g = D.c.g;`

C: `g = D.c.2;`

D: `g = D.c(2);`

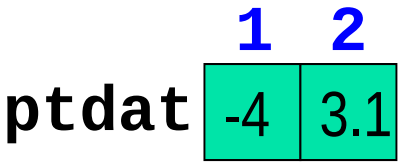
E: *other*

Options for storing the point (-4, 3.1)

- Simple scalars

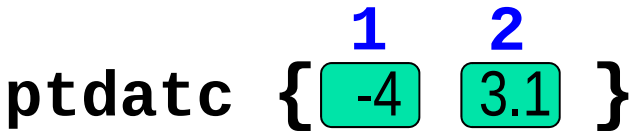
Ungrouped data

- Simple vector

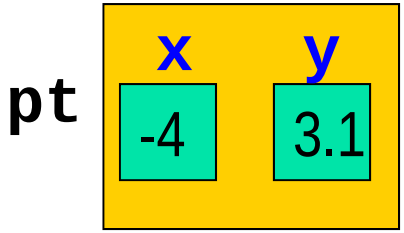


Related data grouped into an array. X-coord implicitly labelled 1; y-coord implicitly labelled 2

- Cell array



- Struct



Related data grouped into a struct variable. Explicit, clear labelling is possible via field names

Different kinds of abstraction

- Packaging procedures (program instructions) into a function
  - A program is a set of functions executed in the specified order
  - Data is passed to (and from) each function
- Packaging data into a structure
  - Elevates thinking
  - Reduces the number of variables being passed to and from functions
- Packaging data, and the instructions that work on those data, into an object
  - A program is the interaction among objects
  - Object-oriented programming (OOP) focuses on the design of data-instructions groupings