- Previous Lecture:
  - Working with images
- Today's Lecture:
  - Characters and strings
- Announcements:
  - Discussion this week in classrooms as listed on roster
  - Project 4 due Mon 10/27 at 11pm

Characters & strings

- We have used strings already:
  - `n= input('Next number: ')`
  - `sprintf('Answer is %d', ans)`
- A string is made up of individual characters, so a string is a 1-d array of characters
- '`CS1112 rocks!`' is a character array of length 13; it has 7 letters, 4 digits, 1 space, and 1 symbol.

'C'	'S'	'1'	'1'	'1'	'2'	' '	'r'	'o'	'c'	'k'	's'	'!'

- Can have 2-d array of characters as well

'C'	'S'	'1'	'1'	'1'	'2'
'r'	'o'	'c'	'k'	's'	'!'

2×6 matrix

Matlab types: `char`, `double`, `uint8`, `logical`

There is not a type "string"! What we call a "string" is a *1-d array of chars*

`a` 'C' 'S' '1'	`a` is a 1-d array with type `char` components. We call `a` a "string" or "char array"
`b = [3 9]`	`b` is a 1-d array with type `double` components. `double` is the default type for numbers in Matlab. We call `b` a "numeric array"
`c = uint8(b)`	`c` is a 1-d array with type `uint8` components. We call `c` a "uint8 array"
`d = rand > .5`	`d` is a scalar of the type `logical`. We call `d` a "boolean value"

Strings are important in computation

Numerical data is often encoded in strings. E.g., a file containing Ithaca weather data begins with the string

`W07629N4226`

meaning

Longitude: 76° 29' West
Latitude: 42° 26' North

We may need to grab hold of the substring `W07629`, convert `076` and `29` to the numeric values 76 and 29, and do some computation

Comparison of genomic sequences is another example of string computation

- E.g., looking for a pattern:
  Given the sequence `ATTCTGACCTCGATC…`
  Look for the pattern `ACCT`
- E.g., quantifying the difference between sequences:

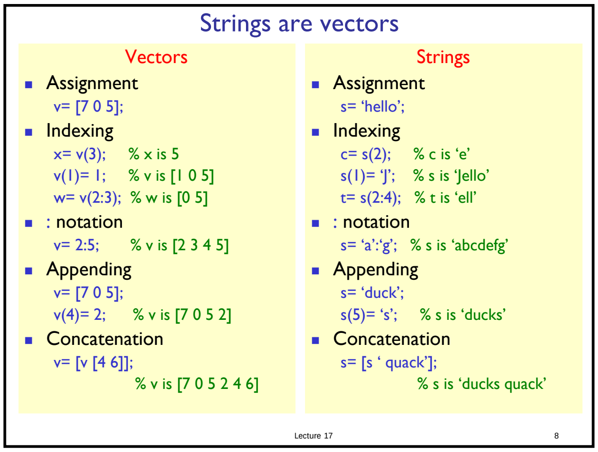
```
ATTCTGACCTCGATC
ATTCGTGACCTCGAT
```

What if this nucleotide is removed?

Single quotes enclose strings in Matlab

Anything enclosed in single quotes is a string (*even if it looks like something else*)

- `'100'` is a character array (string) of length 3
- `100` is a numeric value
- `'pi'` is a character array of length 2
- `pi` is the built-in constant 3.1416…
- `'x'` is a character (vector of length 1)
- `x` may be a variable name in your program

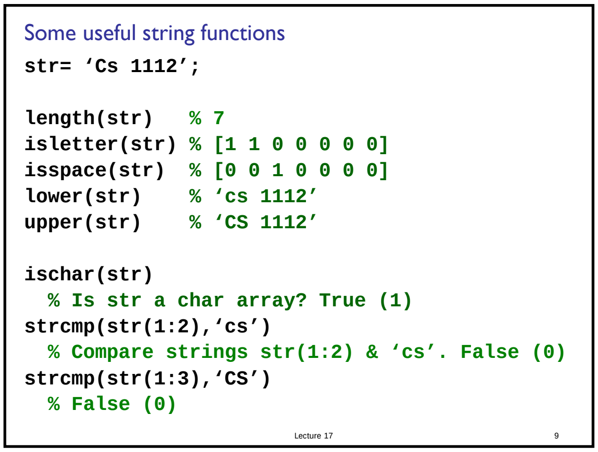


Strings are vectors

Vectors	Strings
■ Assignment v= [7 0 5];	■ Assignment s= 'hello';

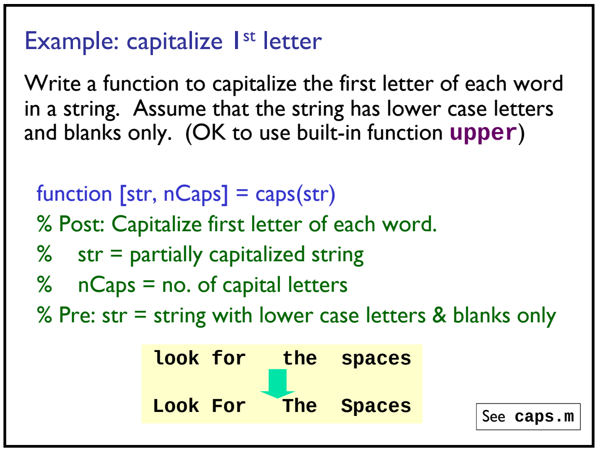
■ Indexing
x= v(3);   % x is 5
v(1)= 1;   % v is [1 0 5]
w= v(2:3); % w is [0 5]
	■ Indexing
	c= s(2); % c is 'e'
	s(1)= 'J'; % s is 'Jello'
	t= s(2:4); % t is 'ell'

■ : notation v= 2:5; % v is [2 3 4 5]	■ : notation s= 'a':'g'; % s is 'abcdefg'
■ Appending v= [7 0 5]; v(4)= 2; % v is [7 0 5 2]	■ Appending s= 'duck'; s(5)= 's'; % s is 'ducks'
■ Concatenation v= [v [4 6]]; % v is [7 0 5 2 4 6]	■ Concatenation s= [s ' quack']; % s is 'ducks quack'



Some useful string functions

```
str= 'Cs 1112';

length(str)   % 7
isletter(str) % [1 1 0 0 0 0 0]
isspace(str)  % [0 0 1 0 0 0 0]
lower(str)    % 'cs 1112'
upper(str)    % 'CS 1112'

ischar(str)
  % Is str a char array? True (1)
strcmp(str(1:2),'cs')
  % Compare strings str(1:2) & 'cs'. False (0)
strcmp(str(1:3),'CS')
  % False (0)
```



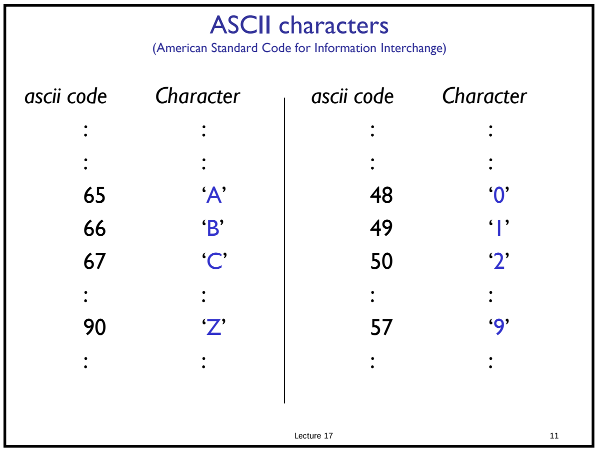
Example: capitalize 1st letter

Write a function to capitalize the first letter of each word in a string. Assume that the string has lower case letters and blanks only. (OK to use built-in function `upper`)

```
function [str, nCaps] = caps(str)
% Post: Capitalize first letter of each word.
%    str = partially capitalized string
%    nCaps = no. of capital letters
% Pre: str = string with lower case letters & blanks only
```

```
look for   the   spaces

Look For   The   Spaces
```

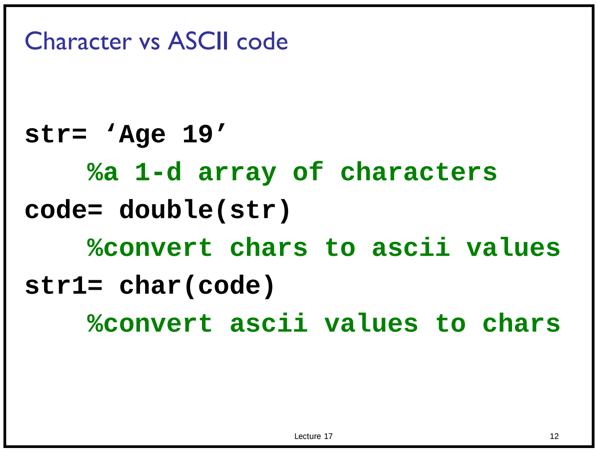
See `caps.m`



ASCII characters

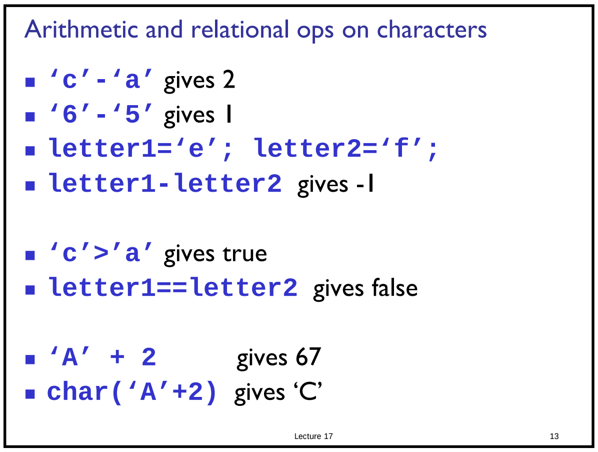
(American Standard Code for Information Interchange)

ascii code	*Character*	*ascii code*	*Character*
:	:	:	:
:	:	:	:
65	'A'	48	'0'
66	'B'	49	'1'
67	'C'	50	'2'
:	:	:	:
90	'Z'	57	'9'
:	:	:	:



Character vs ASCII code

```
str= 'Age 19'
    %a 1-d array of characters
code= double(str)
    %convert chars to ascii values
str1= char(code)
    %convert ascii values to chars
```

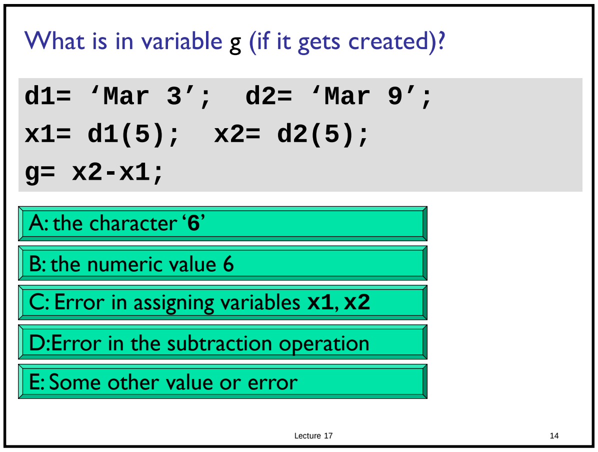


Arithmetic and relational ops on characters

- `'c'-'a'` gives 2
- `'6'-'5'` gives 1
- `letter1='e'; letter2='f';`
- `letter1-letter2` gives -1

- `'c'>'a'` gives true
- `letter1==letter2` gives false

- `'A' + 2` gives 67
- `char('A'+2)` gives 'C'



What is in variable g (if it gets created)?

```
d1= 'Mar 3';  d2= 'Mar 9';
x1= d1(5);  x2= d2(5);
g= x2-x1;
```

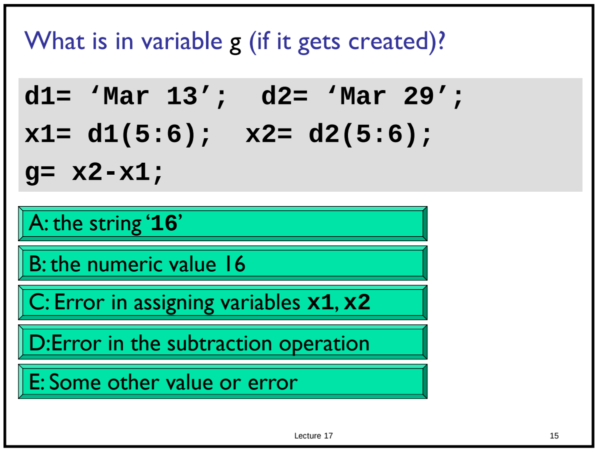
A: the character **'6'**

B: the numeric value 6

C: Error in assigning variables **x1, x2**

D:Error in the subtraction operation

E: Some other value or error



What is in variable g (if it gets created)?

```
d1= 'Mar 13';  d2= 'Mar 29';
x1= d1(5:6);  x2= d2(5:6);
g= x2-x1;
```

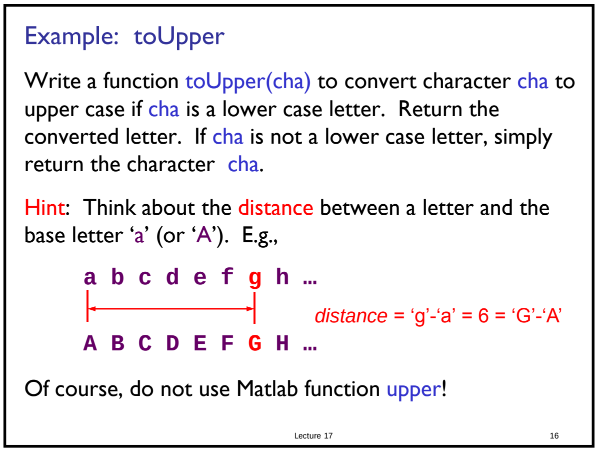
A: the string **'16'**

B: the numeric value 16

C: Error in assigning variables **x1, x2**

D:Error in the subtraction operation

E: Some other value or error



Example: toUpper

Write a function toUpper(cha) to convert character cha to upper case if cha is a lower case letter. Return the converted letter. If cha is not a lower case letter, simply return the character cha.

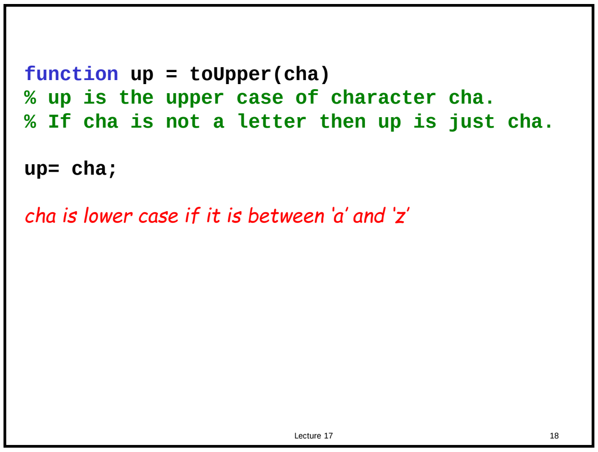
Hint: Think about the distance between a letter and the base letter 'a' (or 'A'). E.g.,

a b c d e f g h …

distance = 'g'-'a' = 6 = 'G'-'A'

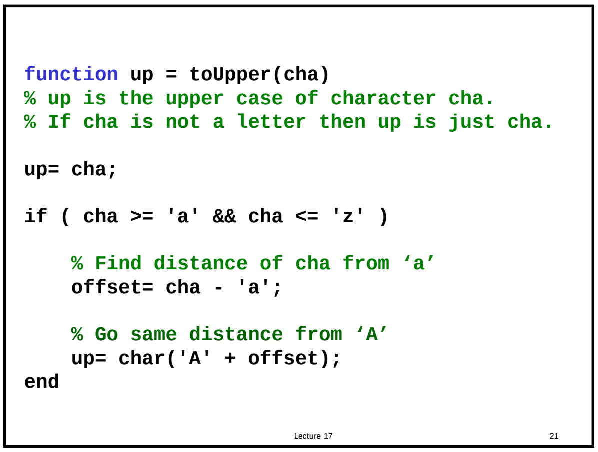
A B C D E F G H …

Of course, do not use Matlab function upper!

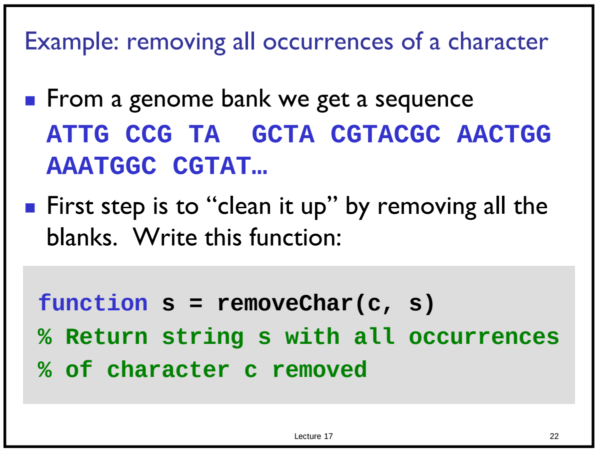


```
function up = toUpper(cha)
% up is the upper case of character cha.
% If cha is not a letter then up is just cha.

up= cha;
```

cha is lower case if it is between 'a' and 'z'



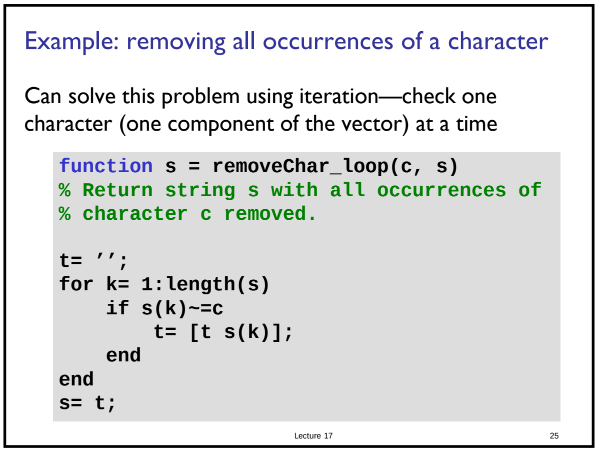
```
function up = toUpper(cha)
% up is the upper case of character cha.
% If cha is not a letter then up is just cha.

up= cha;

if ( cha >= 'a' && cha <= 'z' )

    % Find distance of cha from 'a'
    offset= cha - 'a';

    % Go same distance from 'A'
    up= char('A' + offset);
end
```



Example: removing all occurrences of a character

- From a genome bank we get a sequence **ATTG CCG TA GCTA CGTACGC AACTGG AAATGGC CGTAT…**
- First step is to "clean it up" by removing all the blanks. Write this function:

```
function s = removeChar(c, s)
% Return string s with all occurrences
% of character c removed
```



Example: removing all occurrences of a character

Can solve this problem using iteration—check one character (one component of the vector) at a time

```
function s = removeChar_loop(c, s)
% Return string s with all occurrences of
% character c removed.

t= '';
for k= 1:length(s)
    if s(k)~=c
        t= [t s(k)];
    end
end
s= t;
```

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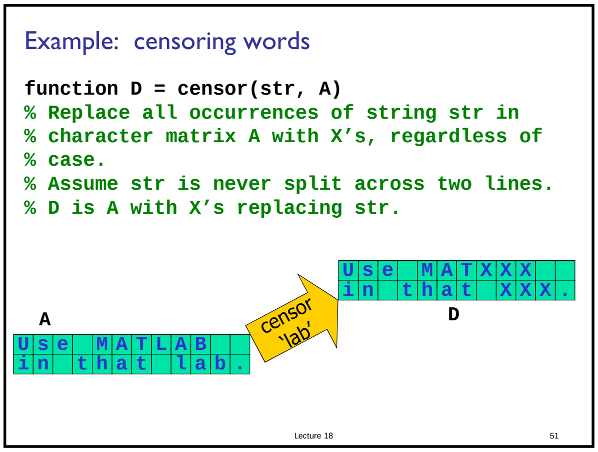

Example: censoring words

```
function D = censor(str, A)
% Replace all occurrences of string str in
% character matrix A with X's, regardless of
% case.
% Assume str is never split across two lines.
% D is A with X's replacing str.
```

A

U	s	e		M	A	T	L	A	B		
i	n		t	h	a	t		l	a	b	.

D

U	s	e		M	A	T	X	X	X		
i	n		t	h	a	t		X	X	X	.

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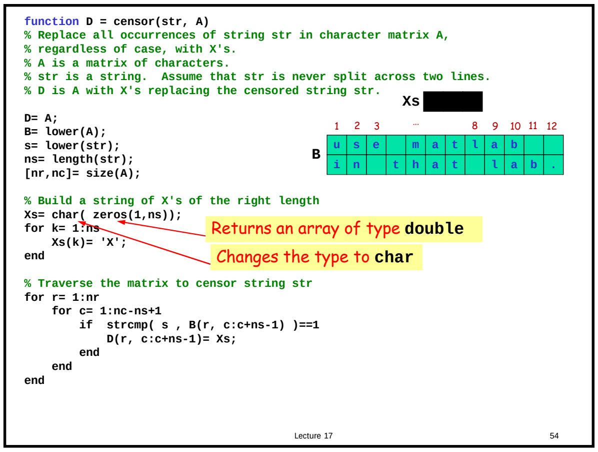

```
function D = censor(str, A)
% Replace all occurrences of string str in character matrix A,
% regardless of case, with X's.
% A is a matrix of characters.
% str is a string.  Assume that str is never split across two lines.
% D is A with X's replacing the censored string str.

D= A;
B= lower(A);
s= lower(str);
ns= length(str);
[nr,nc]= size(A);

% Build a string of X's of the right length
Xs= char( zeros(1,ns));
for k= 1:ns
    Xs(k)= 'X';
end

% Traverse the matrix to censor string str
for r= 1:nr
    for c= 1:nc-ns+1
        if  strcmp( s , B(r, c:c+ns-1) )==1
            D(r, c:c+ns-1)= Xs;
        end
    end
end
```

B

1	2	3		...			8	9	10	11	12
u	s	e		m	a	t	l	a	b		
i	n		t	h	a	t		l	a	b	.

Returns an array of type **double**

Changes the type to **char**

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