Hi! This is CS50.

- If just added, see cs50.harvard.edu for website. Email heads@cs50.harvard.edu with questions.
- If you have trouble seeing projector, see live.cs50.io/screen for a live feed, Wi-Fi permitting.
- If uncomfy asking questions during lecture, post to cs50.harvard.edu/discourse!
- Problem Set 2, due Thu 9/27 at 11:59pm, on website this eve.
This is CS50
when clicked

say hello, world
```
#include <stdio.h>

int main(void)
{
    printf("hello, world\n");
}
```
#include <stdio.h>

int main(void)
{
    printf("hello, world\n");
}
```c
#include <stdio.h>

int main(void)
{
    printf("hello, world\n");
}
```
clang hello.c

./a.out
clang -o hello hello.c

./hello
make hello

./hello
#include <stdio.h>

int main(void)
{
    printf("hello, world\n");
}

```c
#include <cs50.h>
#include <stdio.h>

int main(void)
{
    string name = get_string("Name: ");
    printf("hello, %s\n", name);
}
```
clang hello.c

./a.out
clang hello.c -lcs50

./a.out
clang -o hello hello.c -lcs50

./hello
make hello

./hello
compiling
preprocessing

compiling

assembling

linking
preprocessing

compiling

assembling

linking
#include <cs50.h>
#include <stdio.h>

int main(void)
{
    string name = get_string("Name: ");
    printf("hello, %s\n", name);
}
```c
#include <cs50.h>
#include <stdio.h>

int main(void)
{
    string name = get_string("Name: ");
    printf("hello, %s\n", name);
}
```
string get_string(string prompt);
#include <stdio.h>

int main(void)
{
    string name = get_string("Name: ");
    printf("hello, %s
", name);
}
string get_string(string prompt);
#include <stdio.h>

int main(void)
{
    string name = get_string("Name: ");
    printf("hello, %s\n", name);
}
string get_string(string prompt);
int printf(const char *format, ...);

int main(void)
{
    string name = get_string("Name: ");
    printf("hello, %s
", name);
}
string get_string(string prompt);
int printf(const char *format, ...);
...

int main(void)
{
    string name = get_string("Name: ");
    printf("hello, %s\n", name);
}
preprocessing

compiling

assembling

linking
string get_string(string prompt);
int printf(const char *format, ...);
...

int main(void)
{
    string name = get_string("Name: ");
    printf("hello, %s\n", name);
}

main:                                   # @main
    .cfi_startproc
    # BB#0:
    pushq   %rbp
    .Ltmp0:
       .cfi_def_cfa_offset 16
    .Ltmp1:
       .cfi_offset %rbp, -16
       movq   %rsp, %rbp
    .Ltmp2:
       .cfi_def_cfa_register %rbp
       subq   $16, %rsp
       xorl   %eax, %eax
       movl   %eax, %edi
       movabsq $.L.str, %rsi
       movb   $0, %al
       callq  get_string
       movabsq $.L.str.1, %rdi
       movq   %rax, -8(%rbp)
       movq   -8(%rbp), %rsi
       movb   $0, %al
       callq  printf
    ...

main:                                   # @main
    .cfi_startproc
    # BB#0:
    pushq   %rbp
    .Ltmp0:
        .cfi_def_cfa_offset 16
    .Ltmp1:
        .cfi_offset %rbp, -16
        movq   %rsp, %rbp
    .Ltmp2:
        .cfi_def_cfa_register %rbp
        subq   $16, %rsp
        xorl   %eax, %eax
        movl   %eax, %edi
        movabsq  $.L.str, %rsi
        movb   $0, %al
        callq  get_string
        movabsq  $.L.str.1, %rdi
        movq    %rax, -8(%rbp)
        movq    -8(%rbp), %rsi
        movb   $0, %al
        callq  printf
    ...
main:

.cfi_startproc

BB#0:

pushq %rbp

.Ltmp0:

.cfi_def_cfa_offset 16

.Ltmp1:

.cfi_offset %rbp, -16

movq %rsp, %rbp

.Ltmp2:

.cfi_def_cfa_register %rbp

subq $16, %rsp

xorl %eax, %eax

movl %eax, %edi

movabsq $.L.str, %rsi

movb $0, %al

callq get_string

movabsq $.L.str.1, %rdi

movq %rax, -8(%rbp)

movq -8(%rbp), %rsi

movb $0, %al

callq printf

...
preprocessing
compiling
assembling
linking
main:                                   # @main
    .cfi_startproc
    # BB#0:
        pushq    %rbp
    .Ltmp0:
        .cfi_def_cfa_offset 16
    .Ltmp1:
        .cfi_offset %rbp, -16
        movq    %rsp, %rbp
    .Ltmp2:
       .cfi_def_cfa_register %rbp
        subq    $16, %rsp
        xorl    %eax, %eax
        movl    %eax, %edi
        movabsq    $.L.str, %rsi
        movb    $0, %al
        callq    get_string
        movabsq    $.L.str.1, %rdi
        movq    %rax, -8(%rbp)
        movq    -8(%rbp), %rsi
        movb    $0, %al
        callq    printf
    ...

...
preprocessing
compiling
assembling
linking
hello.c
cs50.c       printf.c
printf.c
array
string
plaintext $\rightarrow$ ciphertext
HI!
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<th>8501</th>
<th>115</th>
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<th>6491</th>
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<td>BEI STOPFF.</td>
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</tbody>
</table>
like a pail on sculpture, till another man
took the burden from him and went up
to the house with his dead.

When Mr. Raleigh entered the house
again, it was at break of day. Some
one opened the library-door and beckon-
ed him in. Marguerite sprang into his
arms.

"What if she had died?" said Mrs.
Purcell, with her swill satiric breath, and
fishing a web of muslin over her arms.
"See! I had got out the shroud. As it
is, we drink shill and say grace at break-
dfast. The funeral baked-meats shall
coldly furnish forth the marriage-feast.
You men are all alike. Le Roi est mort!
Vive le Roi!"

PAUL REVERE'S RIDE.

Listen, my children, and you shall hear
Of the midnight ride of Paul Revere,
On the eighteenth of April, in Seventy-Five:
Hardly a man is now alive
Who remembers that famous day and year.

He said to his friend, — "If the British march
By land or sea from the town to-night,
Hang a lantern aloft in the belfry-arch
Of the North-Church-tower, as a signal-light,—
One if by land, and two if by sea;
And I on the opposite shore will be,
Ready to ride and spread the alarm
Through every Middlesex village and farm,
For the country-folk to be up and to arm."

Then he said good-night, and with muffled ear
Silently rowed to the Charlestown shore,
Just as the moon rose over the bay,
Where swinging wide at her moorings lay
The Sovereign, British man-of-war:
A phantom ship, with each mast and spar
Across the moon, like a prison-bar,
And a huge, black bulk, that was magnified
By its own reflection in the tide.

Meanwhile, his friend, through alley and street
Wanders and watches with eager ears,
Till in the silence around him he hears
The muster of men at the barrack-door,
The sound of arms, and the tramp of foot,
And the measured tread of the grenadiers
Marching down to their boats on the shore.

Then he climbed to the tower of the church,
Up the wooden stairs, with stealthy tread,
plaintext $\rightarrow$ key $\rightarrow$ ciphertext $\rightarrow$ ciphertext
I LOVE YOU
73 LOVE YOU
73 76 79 V E Y O U
J M P W 70 90 80 86
#include <stdio.h>

int main(void)
{
    ...
}

```c
#include <stdio.h>

int main(void)
{
    ...
}
```
#include <stdio.h>

int main(int argc, string argv[])
{
    ...
}

#include <stdio.h>

int main(int argc, string argv[])
{
    ...  
}

#include <stdio.h>

int main(int argc, string argv[])
{
    ...
}

#include <stdio.h>

int main(void)
{
    ...

    ...
}
Bubble Sort
repeat until no swaps
  for i from 0 to n-2
    if i'th and i+1'th elements out of order
      swap them
Selection Sort
for i from 0 to n-1
    find smallest element between i'th and n-1'th
    swap smallest with i'th element
$(n - 1)$
(n – 1) + (n – 2)
\((n - 1) + (n - 2) + \ldots + 1\)
\[(n - 1) + (n - 2) + \ldots + 1\]

\[n(n - 1)/2\]
$(n - 1) + (n - 2) + ... + 1$

$n(n - 1)/2$

$(n^2 - n)/2$
\[(n - 1) + (n - 2) + \ldots + 1\]  
\[n(n - 1)/2\]  
\[(n^2 - n)/2\]  
\[n^2/2 - n/2\]
(n - 1) + (n - 2) + ... + 1

n(n - 1)/2

(n^2 - n)/2

n^2/2 - n/2

O(n^2)
\[ n^2/2 - n/2 \]
\( \frac{n^2}{2} - \frac{n}{2} \)

\( 1,000,000^2/2 - 1,000,000/2 \)
\[ n^2/2 - n/2 \]
\[ 1,000,000^2/2 - 1,000,000/2 \]
\[ 500,000,000,000 - 500,000 \]
\( \frac{n^2}{2} - \frac{n}{2} \)

\( 1,000,000^2/2 - 1,000,000/2 \)

\( 500,000,000,000 - 500,000 \)

\( 499,999,500,000 \)
\[
n^2/2 - n/2 \\
1,000,000^2/2 - 1,000,000/2 \\
500,000,000,000 - 500,000 \\
499,999,500,000 \\
O(n^2)
\]
$O(n^2)$

$O(n \log n)$

$O(n)$

$O(\log n)$

$O(1)$
\( \Theta(n^2) \)

\( \Theta(n \log n) \)

\( \Theta(n) \)

\( \Theta(\log n) \)

\( \Theta(1) \)
Merge Sort
on input of n elements
  if n < 2
    return
  else
    sort left half of elements
    sort right half of elements
    merge sorted halves
This is CS50