# Computer Systems and Organization 2

# themes

automating building software

- libraries, taking advantage of incremental compilation

sharing machines

- multiple users/programs on one system

parallelism and concurrency

- doing two+ things at once

under the hood of sockets

- layered design of networks
- implementing secure communication

under the hood of fast processors

- caching, (hidden) parallelism, avoiding idle time

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# make

```
$ ./foo.exe
...
...
$ edit readline.c
$ make
clang -g -O -Wall -c readline.c -o readline.o
ar rcs terminal.o readline.o libreadline.a
clang -o foo.exe foo.o foo-utility.o -L. -lreadline
$
```

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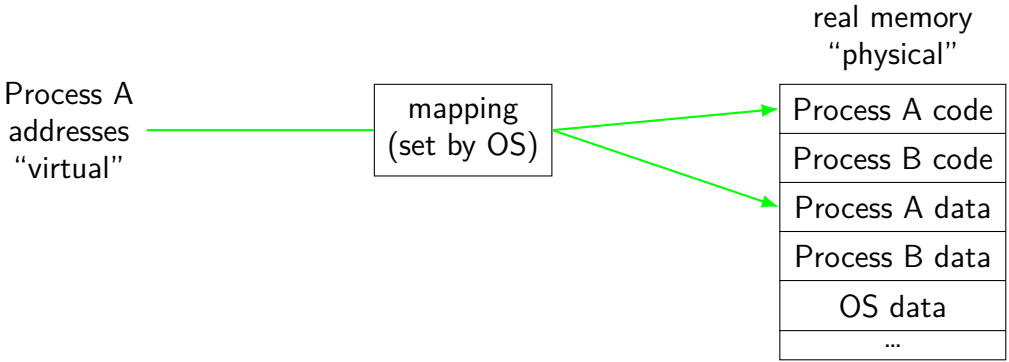
# address translation



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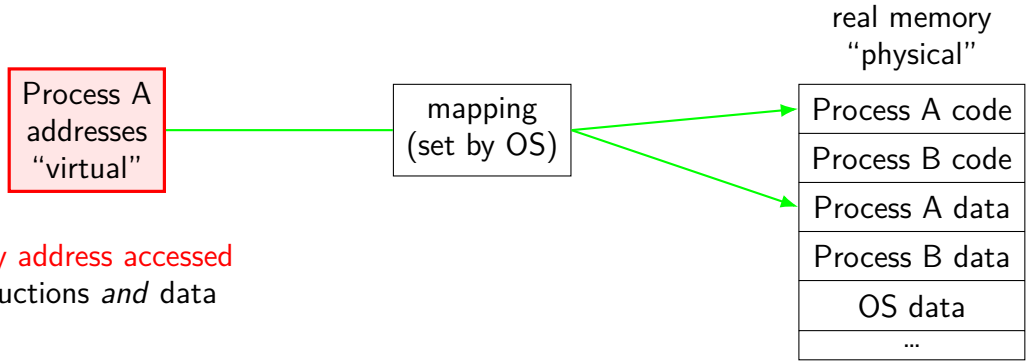
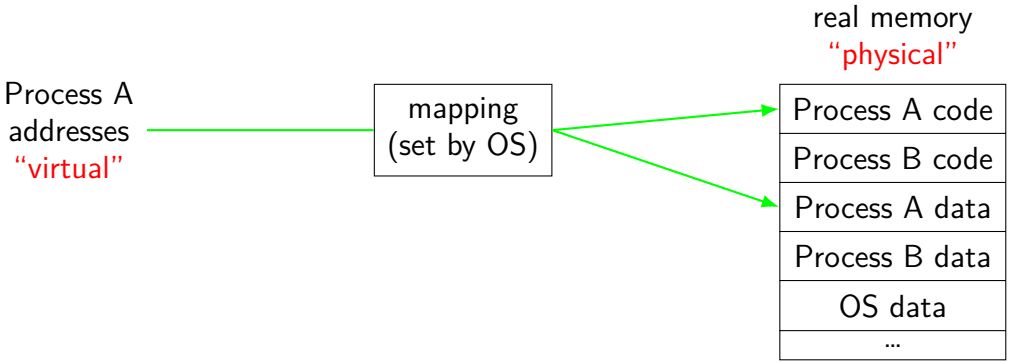


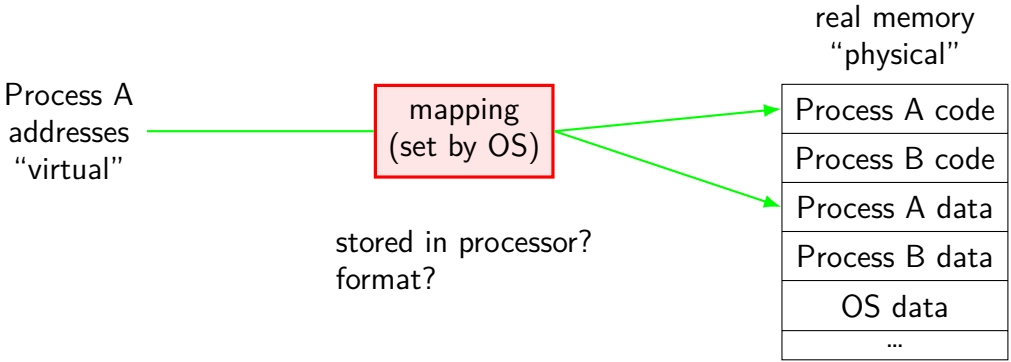

every address accessed
instructions *and* data

# address translation



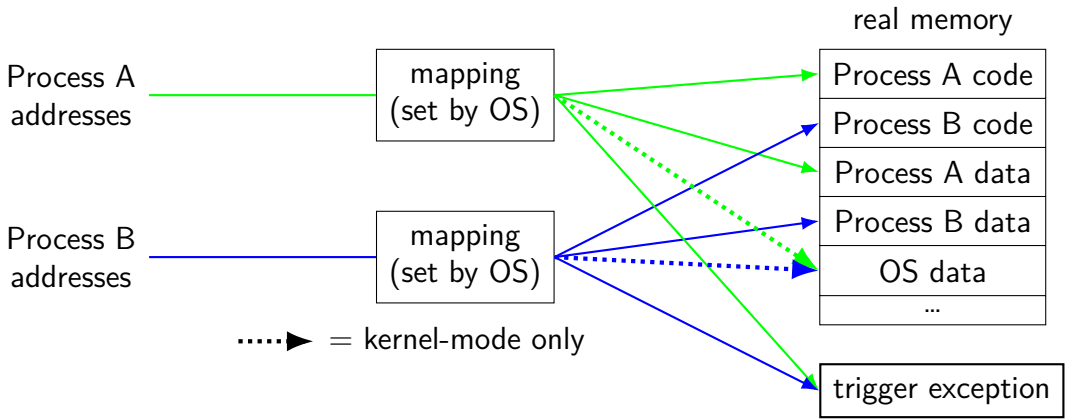

program addresses are 'virtual'
real addresses are 'physical'
can be different sizes!

# address translation



# address spaces

illuision of dedicated memory



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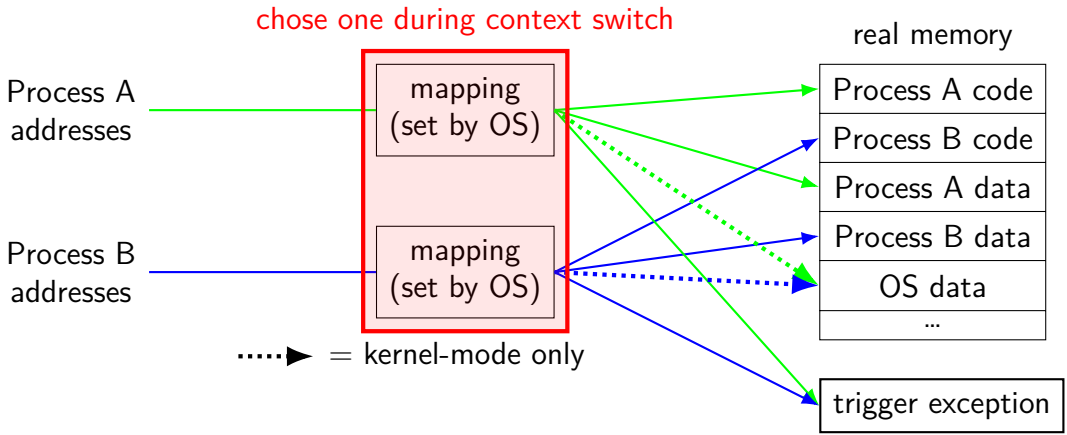

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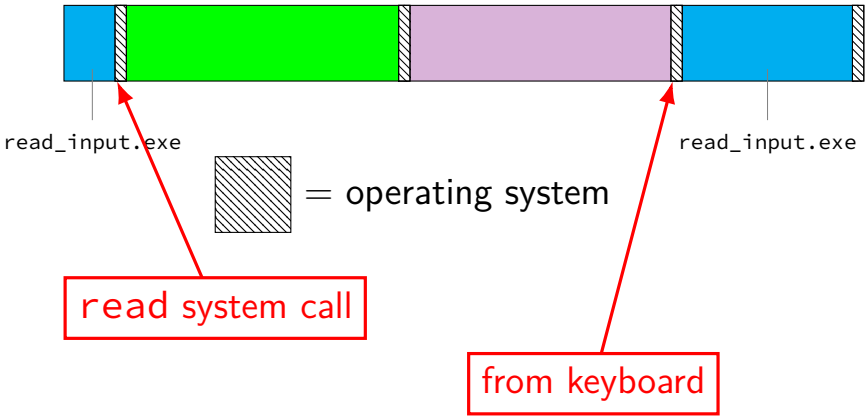
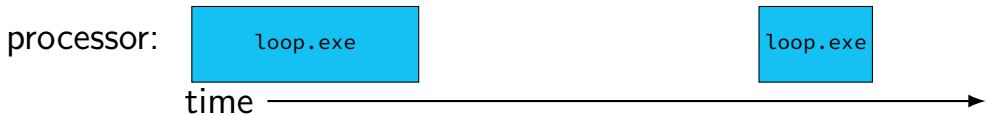
# keyboard input timeline



# time multiplexing



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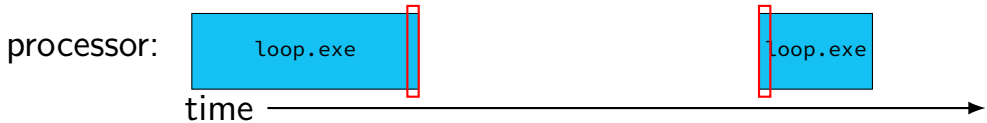
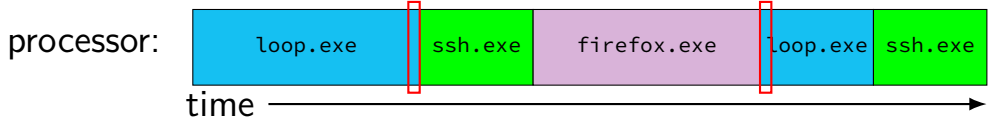



```
...
call get_time
    // whatever get_time does
movq %rax, %rbp
```

million cycle delay

```
call get_time
    // whatever get_time does
subq %rbp, %rax
...
```

# time multiplexing




```
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call get_time
    // whatever get_time does
movq %rax, %rbp
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million cycle delay

```
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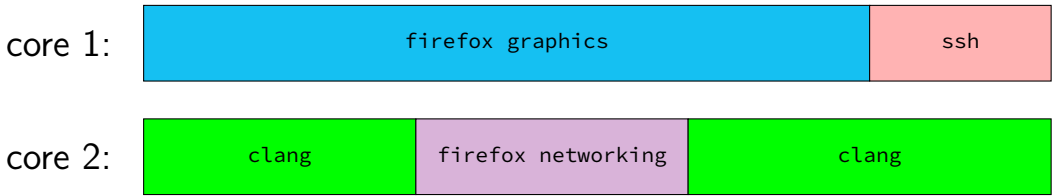
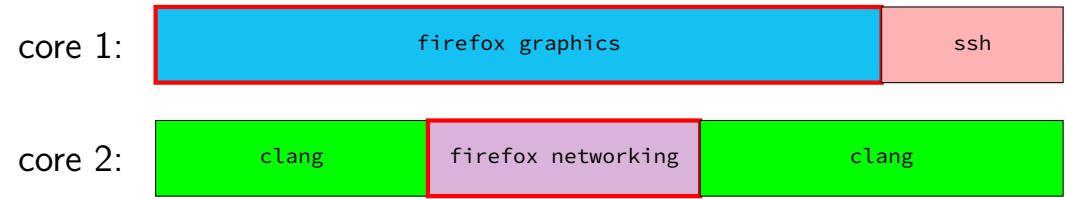
    // whatever get_time does
subq %rbp, %rax
...
```

# multiple cores+threads




multiple cores? each core still divided up

# multiple cores+threads




one program with multiple *threads*

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# permissions

```
$ ls /u/other/secret
ls: cannot open directory '/u/other/secret': Permission denied
$ shutdown
shutdown: Permission denied
```

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# layers

| | | |
|---|---|---|
| application | HTTP, SSH, SMTP, ... | application-defined meanings |
| transport | TCP, UDP, ... | reach correct program, reliablity/streams |
| network | IPv4, IPv6, ... | reach correct machine (across networks) |
| link | Ethernet, Wi-Fi, ... | coordinate shared wire/radio |
| physical | ... | encode bits for wire/radio |

# names and addresses

| name | address |
|---|---|
| logical identifier | location/how to locate |
| variable `counter` | memory address `0x7FFF9430` |
| DNS name `www.virginia.edu` | IPv4 address `128.143.22.36` |
| DNS name `mail.google.com` | IPv4 address `216.58.217.69` |
| DNS name `mail.google.com` | IPv6 address `2607:f8b0:4004:80b::2005` |
| DNS name `reiss-t3620.cs.virginia.edu` | IPv4 address `128.143.67.91` |
| DNS name `reiss-t3620.cs.virginia.edu` | MAC address `18:66:da:2e:7f:da` |
| service name `https` | port number 443 |
| service name `ssh` | port number 22 |

# secure communication?

how do you know who your socket is to?

who can read what's on the socket?

what can you do to restrict this?

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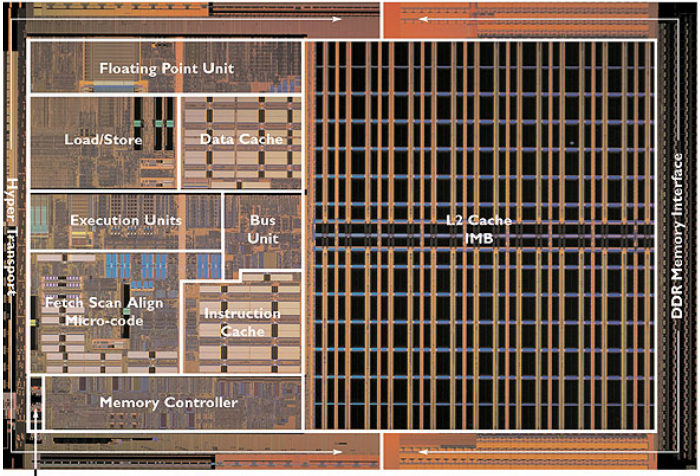
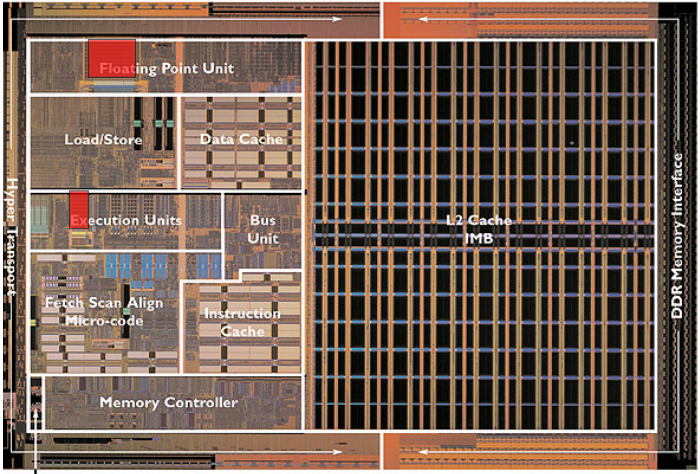
# 2004 CPU




ce: approx 2004 AMD press image of Opteron die;
approx register location via chip-architect.org (Hans de Vries)

# 2004 CPU




Registers

AMD64

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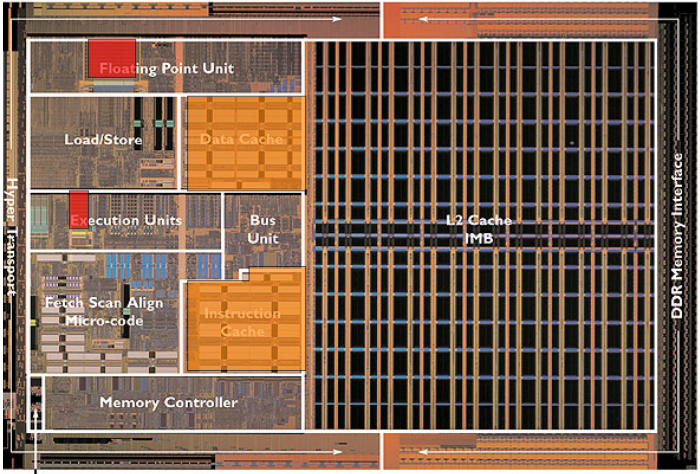
# 2004 CPU





AMD

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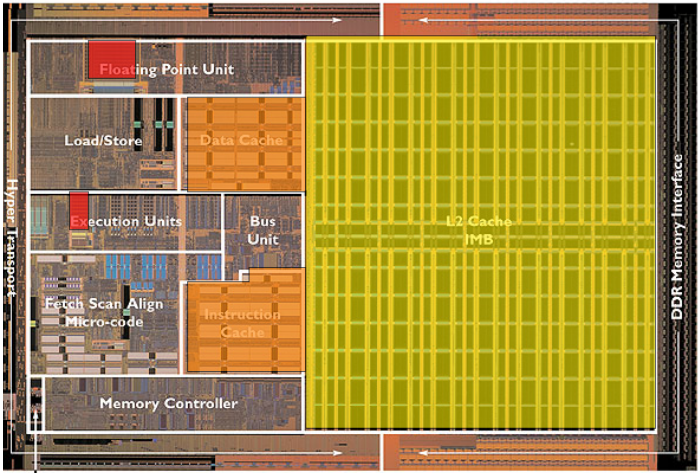


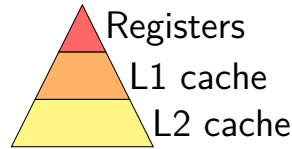


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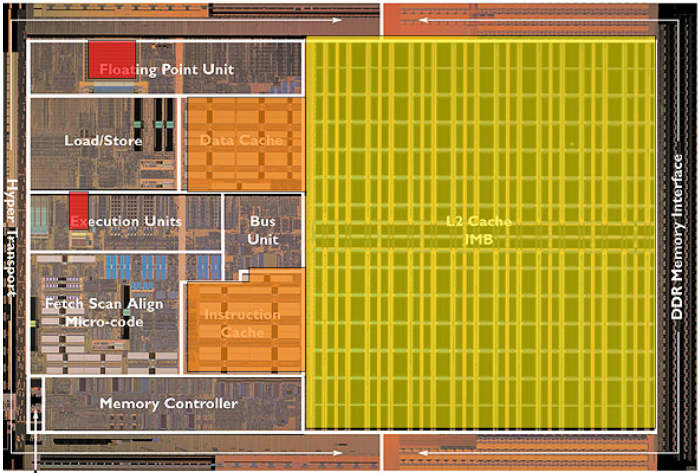


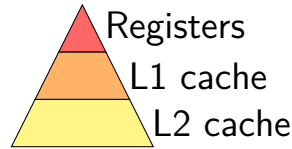


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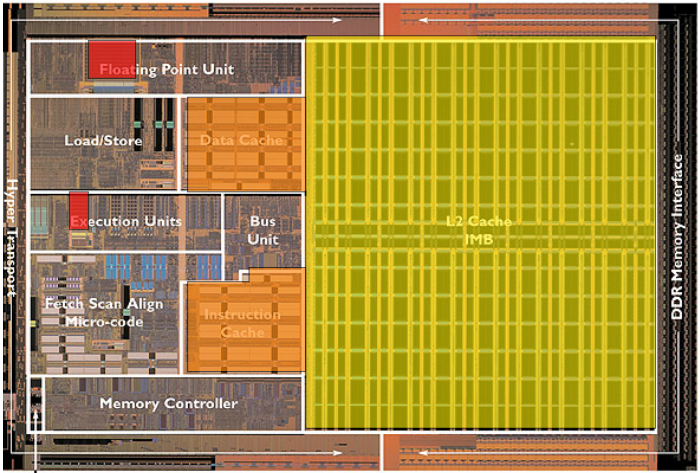


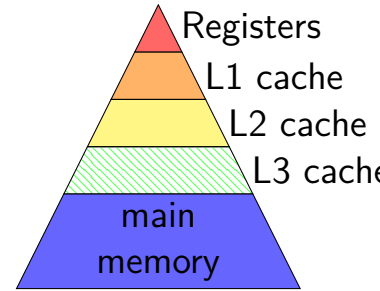


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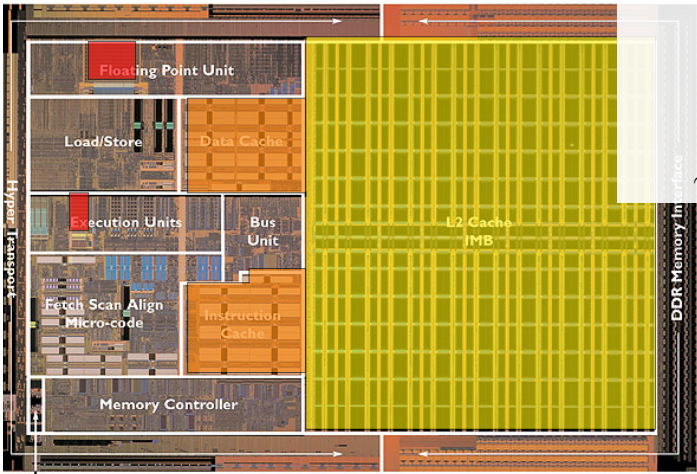


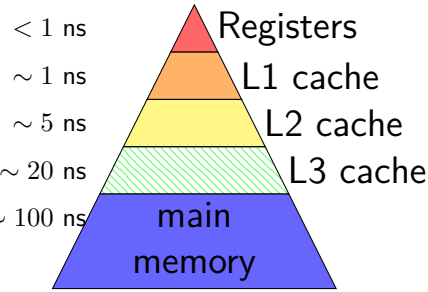


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# some performance examples

```
example1:
    movq $10000000000, %rax
loop1:
    addq %rbx, %rcx
    decq %rax
    jge loop1
    ret
```

about 30B instructions

my desktop: approx 2.65 sec

```
example2:
    movq $10000000000, %rax
loop2:
    addq %rbx, %rcx
    addq %r8, %r9
    decq %rax
    jge loop2
    ret
```

about 40B instructions

my desktop: approx 2.65 sec

# some performance examples

```
example1:
    movq $10000000000, %rax
loop1:
    addq %rbx, %rcx
    decq %rax
    jge loop1
    ret
```

about 30B instructions

my desktop: approx 2.65 sec

```
example2:
    movq $10000000000, %rax
loop2:
    addq %rbx, %rcx
    addq %r8, %r9
    decq %rax
    jge loop2
    ret
```

about 40B instructions

my desktop: approx 2.65 sec

# logistics

# labs

attend lab in person and get checked off by TA, *or*

(most labs) submit something to submission site and we'll grade it

- submit to submission site? don't care if you attend the lab
- more strict about submissions without checkoffs
- in-person lab checkoff of incomplete lab at least 50% credit
- if both checkoff + submission, will use higher score

some labs will basically require attendance

- or contact me for other arrangements if you can't (sick, etc.)
- logistically won't work otherwise — e.g. code review

# lab collaboration and submissions

please collaborate on labs!

when working with others on lab and submitting code files

please indicate who you worked with in those files

- via comment or similar

# lab space

if labs are full, might kick out students from ‘wrong’ lab section

for 3:30pm, please come to registered room

for 5pm, 6:30pm, based on registration
should only need one room

plan: those labs Rice 130 only

- will send announcement/have something posted on unused room

# homeworks

several homework assignments

done individually

generally due on Fridays

(tentative dates on schedule)

# homework/lab automatic testing

some homeworks/labs have automatic testing

with some delay after you submit

- usually 10s of minutes
- depending on assignment, number of submissions in queue
- if you submit very early, testing program might not be setup yet

when testing program doesn't understand/can't test something, left for manual grading ("not yet graded")

intention is that testing results are not surprises
if you did some manual testing (no hidden requirements, etc.)

if you think testing program made a mistake,
please submit regrade request

# warmup assignment

first homework

due week from Friday 8 Sep @ 11:59pm

write C function to split a string into array of strings

- with dynamic memory allocation

write C program to call function using input/command-line arguments

write Makefile for it (next topic, next week's lab)

# quizzes

released evening after Thursday lecture

- starting *next* week

due 15 minutes before lecture on Tuesdays

about lecture and/or lab from the prior week

4–6 questions

*individual*, open book, open notes, open Internet

- okay: looking up resources/tutorials/etc.
- not okay: asking Stack Overflow the quiz question
- not okay: IMing your friend the quiz question

# on help on quiz questions

I and the TAs won't answer quiz questions...

but we will answer questions about the lecture material, etc.

(and TAs (not you) are responsible for knowing
what they can't answer
but we'd prefer you don't try to test those limits)

# going over past quizzes

have in past gone over quiz Qs in lecture

- either when a lot missed it
- or on request in lecture

also fine office hour/Piazza question

# readings

in lieu of textbook, have readings

mostly written by Prof Tychnoveich (now at UIUC) with edits by me

on website; should be indicated with corresponding lecture

# lecture + assignment sync

generally:
quiz after lecture and/or lab coverage
labs after lecture coverage
homework after lab coverage

means homework (and sometimes quiz)
may be relatively delayed from lecture coverage

# exams

1 final exam

no midterms — instead:

- quizzes count a lot
- slightly more homework/lab than pilot

# development enviroment

official: department machines via SSH or NX (remote desktop)

you can also use your own machines, but...

we will test your code on x86-64 Linux

I haven't checked assignments on a Windows or OS X machine

# getting help

office hours — calendar will be posted on website

- mix of in-person and remote, indicated on calendar
- remote OH will use Discord + online queue
- in-person OH may or may not — indicated on whiteboard, probably

Piazza

- use private questions if homework code, etc.

emailing me (preferably with '3130' in subject)

# collaboration (1)

labs — you can/should work with other students

- everyone should understand the work submitted

homeworks — individual

- write your own code / do not share your code
- can ask/look up conceptual questions of others
- others includes other students, Q&A sites, code generation tools, etc.
- **cite** any sources you use (comments in code)

# collaboration (2)

quizzes — individual

but open book+notes+etc.

can/should have help reviewing lecture/readings/etc.

- legitimate questions for office hours

don't ask other students, stack overflow, gen AI tools, etc. the quiz questions

don't try to find exactly the quiz question on stack overflow

# feedback

anonymous feedback on Canvas

would appreciate feedback (esp. when I can do something)

(but not a good way to ask for regrades, etc.)

# late policy

no late quizzes

one quiz dropped (unconditionally)

90% credit for 0–72 hours late homeworks

for labs that allow submission only

- lab submission due time is 11:59am the next day
- 90% credit for 0–24 hours late

no late lab checkoffs except by special arrangement

# excused lateness

special circumstances?

- illness, emergency, etc.

contact me, we'll figure something out

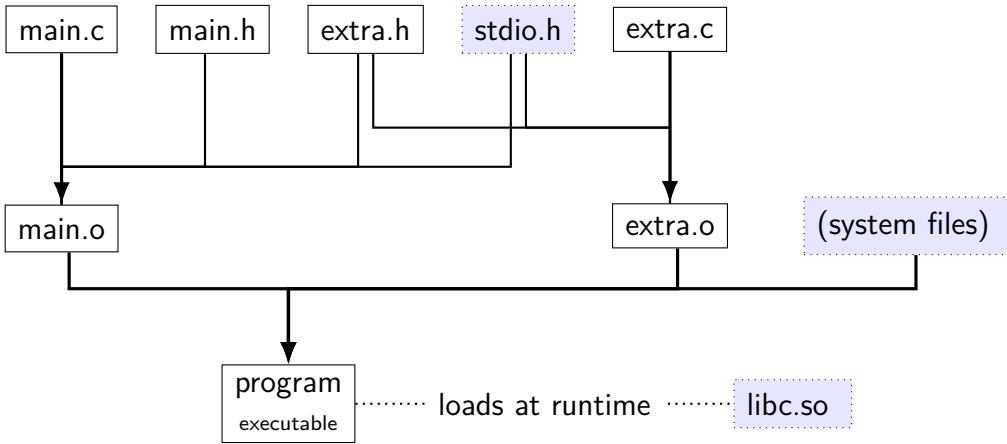
please don't attend lab/etc. sick!

# attendance

- I won't take attendance in lecture
- I will attempt to have lecture recordings
  - sometimes there may be issues with the recording

# building

# files in building C programs [dynamic linking]



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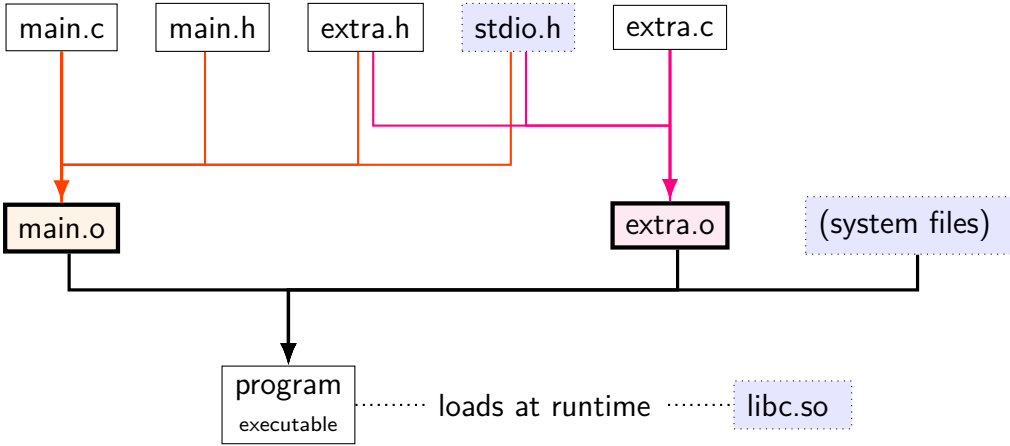
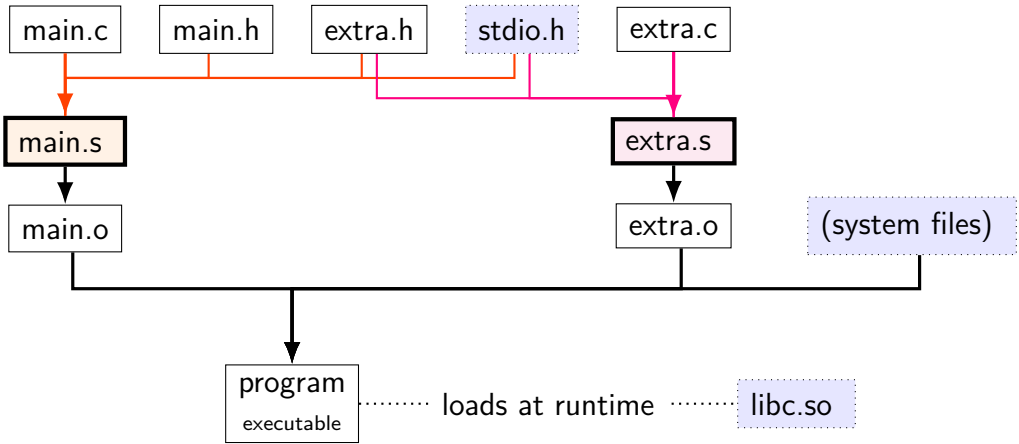


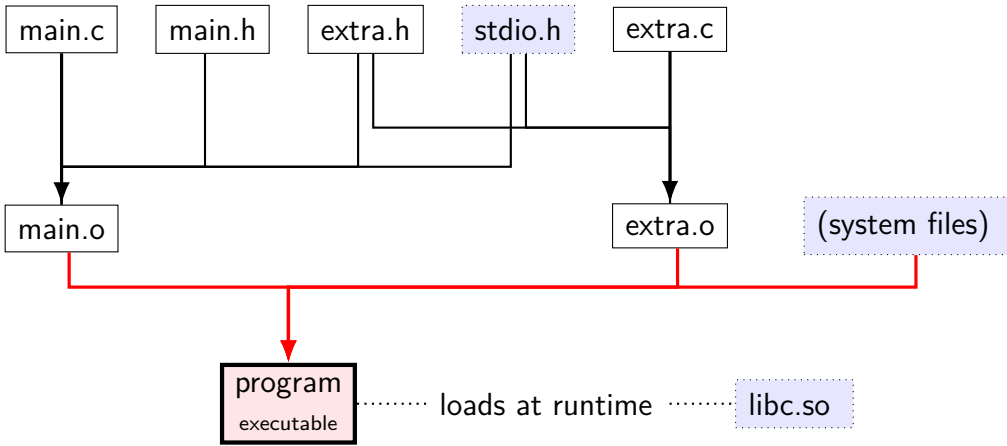

```
clang -c main.c
clang -c extra.c
```

# files in building C programs [dynamic linking]



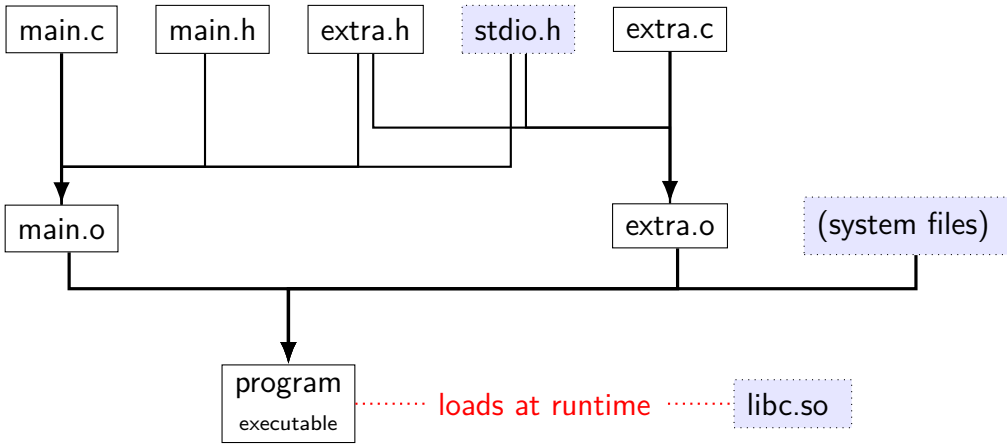

```
clang -S -c main.c
clang -S -c extra.c
```

# files in building C programs [dynamic linking]



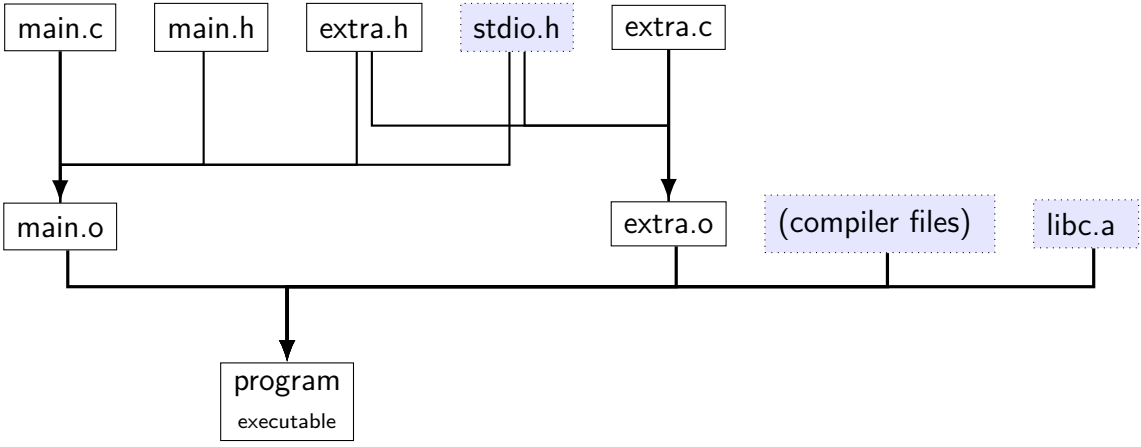

```
clang -o program main.o extra.o
```

# files in building C programs [dynamic linking]




```
./program ...
```

# files in building C programs [static linking]



# file extensions

| name | | |
|---|---|---|
| `.c` | | C source code |
| `.h` | | C header file |
| `.s` | (or `.asm`) | assembly file |
| `.o` | (or `.obj`) | object file (binary of assembly) |
| (none) | (or `.exe`) | executable file |
| .a | (or `.lib`) | statically linked library [collection of .o files] |
| .so | (or `.dll` or `.dylib`) | dynamically linked library [‘shared object’] |

# static libraries

Unix-like *static* libraries: libfoo.a

internally: archive of .o files with index

create: `ar rcs libfoo.a file1.o file2.o …`

use: `cc … -o program -L/path/to/lib … -lfoo`

- no space between `-l` and library name
- `cc` could be clang, gcc, clang++, g++, etc.
- `-L/path/to/lib` not needed if in standard location

# shared libraries

Linux *shared* libraries: libfoo.so

create:

compile .o files with `-fPIC` (position independent code)
then: `cc -shared … -o libfoo.so`

use: `cc …-o program -L/path/to/lib …-lfoo`

# finding shared libraries (1)

```
$ ls
libexample.so  main.c
$ clang -o main main.c -lexample
/usr/bin/ld: cannot find -lexample
clang: error: linker command failed with exit code 1 (use -v
$ clang -o main main.c -L. -lexample
$ ./main
./main: error while loading shared libraries:
    libexample.so: cannot open shared object file: No such fi
```

# finding shared libraries (1)

```
$ ls
libexample.so  main.c
$ clang -o main main.c -lexample
/usr/bin/ld: cannot find -lexample
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$ clang -o main main.c -L. -lexample
$ ./main
./main: error while loading shared libraries:
    libexample.so: cannot open shared object file: No such fi
$ LD_LIBRARY_PATH=. ./main
```

*or*

```
$ export LD_LIBRARY_PATH=.
$ ./main
```

*or*

```
$ clang -o main main.c -L. -lexample -Wl,-rpath .
$ ./main
```

# finding shared libraries (1)

`cc …-o program -L/path/to/lib …-lfoo`

on Linux: `/path/to/lib` only used to create program
program contains `libfoo.so` *without full path*

Linux default: `libfoo.so` expected to be in /usr/lib, /lib, and other 'standard' locations

possible overrides:

LD_LIBRARY_PATH environment variable
paths specified with `-Wl,-rpath=/path/to/lib` when creating executable

# exercise (incremental compilation)

program built from main.c + extra.c

main.c, extra.c both include extra.h, stdio.h

```
clang -c main.c                  # command 1
clang -c extra.c                 # command 2
clang -o program main.o extra.o # command 3
```

What commands need to be rerun if...

Question A: ...main.c changes?

Question B: ...extra.h changes?

# backup slides